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PART 2

LEVEL II

INTERACTIVE COMPOSITE JOINT DESIGN
USER'S MANUAL

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APRIL 1978

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Final Report for Period April 1976 to April 1978

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computing technique was developed to determine the feasibility of combining the several batch computer programs for the analysis of composite joints into one interactive computer program utilizing graphics display. This approach proved successful and produced a design tool for the analysis of bolted or bonded composite joints. The program utilizes the software package provided by TEKTRONIX for the graphics display. The user works at

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the remote on-line graphics terminal in conjunction with the main computing facilities which contain the program.

The final report discusses the summary, conclusion, and recommendations of the work performed. The User's Manual and Programming Manual discuss the input, output, and function of the program.

FOREWORD

This report is one of a series that describes work performed by Douglas Aircraft Company, McDonnell Douglas Corporation, 3855 Lakewood Boulevard, Long Beach, California, 90846, under the Interactive Composite Joint Design Program. This work was sponsored by the U.S. Air Force Flight Dynamics Laboratory, Wright Patterson Air Force Base, under contract F33615-76-C-3058.

This report is divided into three parts. Part 1 is entitled "Final Technical Report", part 2 is entitled "User's Manual", and part 3 is entitled "Programming Manual". The principle investigators and authors are M. K. Smith, C. G. Dietz and L. J. Hart-Smith.

Mr. James R. Johnson was the Air Force Project Engineer during the conceptual phase of this project. During conduct of the program, Mr. Johnson was succeeded by Lt. K. Schrader (AFFDL/FBRA).

This report was submitted to the Air Force on 28 April 1978, and covers work performed during the period April 1976 through April 1978.

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SECTION I

INTRODUCTION

PURPOSE

This program provides the user with a tool to analyze various bolted or bonded composite structural joints. The overall computer program, referred to hereafter as JOINT, is used interactvely; working at a graphics terminal, the user interacts with the computer at execution time by making decisions, entering data, and otherwise directing the behavior of the equipment and program computations. JOINT takes the user step-by-step through the on-line session.

SCOPE

The user may select any of the following types of bolted or bonded joints. Each option has specific capabilities as noted. Reference Figure 1 for typical cross sections.

Bolted Joints

Double- and Single-Lap

The user may determine the optimum joint parameter of thickness, bolt diameter, bolt spacing, and number of bolt rows for a specified load level.

The user may also analyze a given joint design to determine the allowable load level for the joint.

The output summary will always contain the load transferred by each bolt row, its margin of safety, and the failure mode.

Stepped-Lap

Bolt row load distribution margins of safety and failure mode are calculated for the given design parameters and load level.

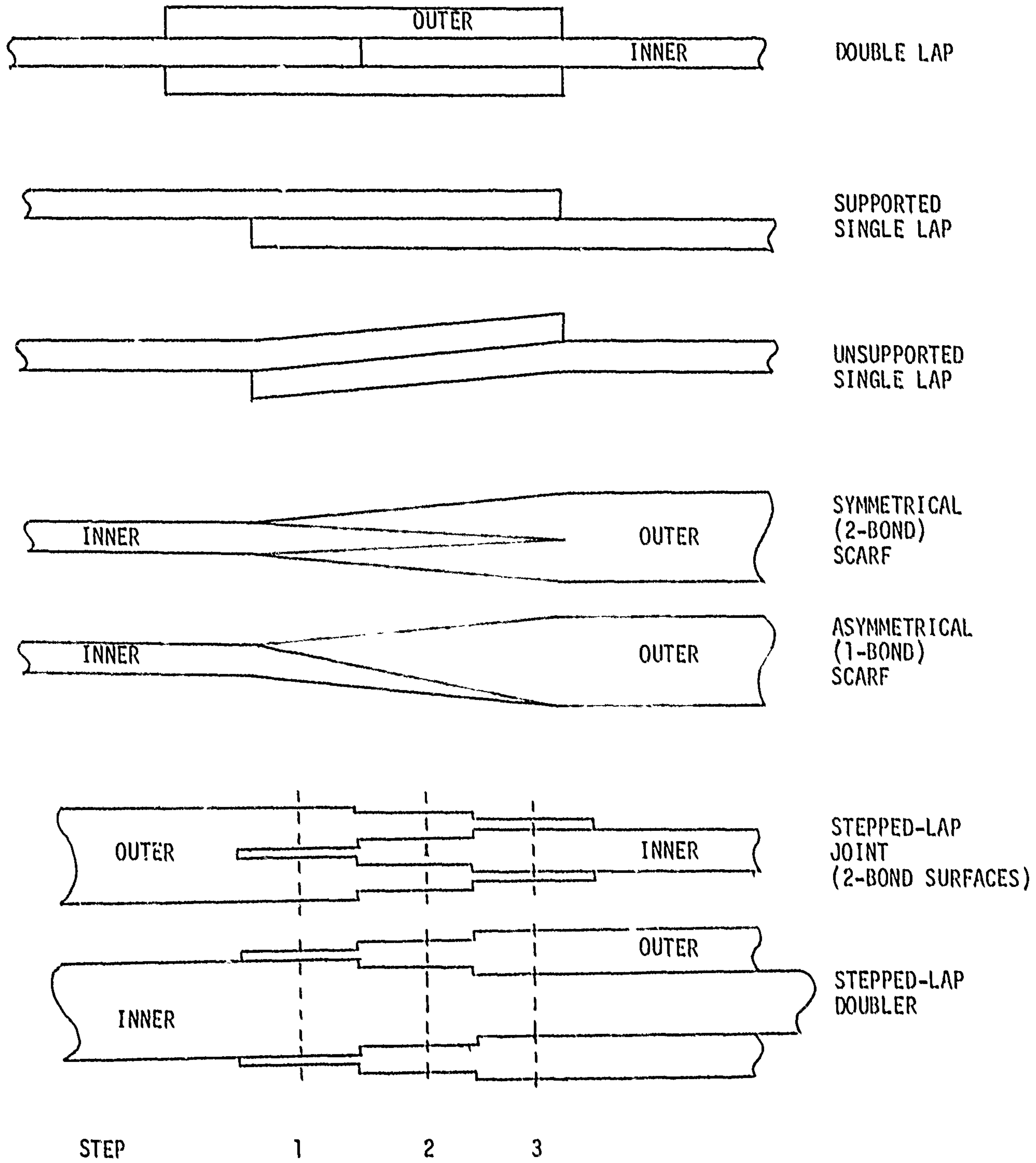


Figure 1. Typical Joint Cross-Section

Bonded Joints

Double-Lap and Supported Single-Lap Joints

The optimum overlap, adhesive strengths, and adherend strength are always calculated. If LOAD $\neq$ 0, the associated maximum adherend and adhesive stresses are calculated. If OVERLAP $\neq$ 0, the associated shear strength of the adhesive is calculated.

Unsupported Single-Lap and Scarf Joints

If LOAD $\neq$ 0, peak adherend and adhesive stresses will be calculated; otherwise the adherend and adhesive strengths will be determined.

If OVERLAP = 0, the above stresses or strength will be computed for a range of 7 ℓ/t values (length/thickness), otherwise these stresses or strengths will be determined for the specified overlap.

Stepped-Lap

The joint design parameters are used to determine the joint strength for elastic, elastic-plastic, and potential adhesive failure modes. The user may analyze either a doubler or joint.

Scarf

If LOAD $\neq$ 0, peak adhesive and adherend stresses will be calculated; otherwise the adhesive strength will be determined.

If OVERLAP = 0, the above stresses or strengths will be computed for a range of 7 ℓ/t values (length/thickness); otherwise these stresses or strengths will be determined for the specified overlap.

Materials

Since the user inputs the properties for the desired bonded joint adhesive and adherends, he is not restricted to any set of materials.

Use of the bolted joints permits the user to select any of the following materials.

HTS Graphite Epoxy (Thornel 300/Narmco 5203): 25% or 37.5% 0° plies

Bolts: Steel or Titanium

SECTION II

HARDWARE

TEKTRONIX TERMINALS

This program, utilizing the Tektronix PLOT10 software package, is to be used specifically on Tektronix 4014/4015 display terminals. If enhanced graphics capability exists, or if other terminals are desired for use, the following features must be available:

- 1024 x 1024 grid size
- 4 character sizes
- 133 maximum characters/line
- 64 lines/page

DATA INPUT AND TRANSMITTAL

Data may be in the form of characters entered from the terminal keyboard, or screen coordinate locations. All data is transmitted by striking the terminal keyboard RETURN key. When the user is prompted for data, the request must be completely filled before the program continues.

Throughout the program, the user is requested to select one of the available choices by transmitting a screen coordinate that identifies that .hoice.

If the choice, or option, is identified by a box around or beside it, the user may send any coordinate within the box. If options are listed on a single line separated by an asterisk (*), only the horizontal location is required. If the screen contains a list of the analysis names, a selection is made by transmitting a coordinate within the boundary of the 8-character name (including blanks).

The user has the initial option to use either the terminal screen cross-hairs or Tektronix graphics tablet to select screen locations.

Screen Crosshair

The terminal screen crosshair is a pair of horizontal and vertical lines, controlled by either a joystick or a pair of thumb screws, depending on the particular terminal equipment. The intersection of the crosshairs indicates the current screen location. If the user is requested to use the crosshair to select an option, the crosshairs will appear on the screen, and remain until a coordinate is transmitted.

Positioning

By using the thumb screws or joystick, the user manipulates the crosshairs to a position on the screen that indicates the selection desired.

Transmittal

The user transmits this location by striking any keyboard key, then the RETURN key. Striking any key will replace the crosshair with the cursor at the intersection point; at this point the selection is fixed and the crosshair cannot be reactivated. The user's only action is the RETURN key to continue processing. If the coordinate does not indicate a valid option, no action will be taken and the crosshairs will be re-established for repositioning.

Graphics Tablet

The graphics tablet, optional equipment for a Tektronix terminal, may be used to indicate a screen coordinate location.

Prompting

When the user is prompted for a screen location, a "TABLET ON" message is displayed at the lower left corner of the terminal screen and a bell is sounded. The user must then place the tablet pen "in presence" (not depressed) on the tablet and strike the RETURN key.

This sequence should be repeated until the screen cursor appears without blinking. The pen is not usable until it can be tracked across the terminal screen.

Positioning and Transmitting

Keeping the pen in presence, move the pen to where the cursor position indicates the desired option on the screen. Pressing the pen activates the location and the cursor will return to the blinking mode. To transmit the location, simply strike the RETURN key.

Re-establishing Cursor

If the location is not valid, the message and bell will be activated again and the user must repeat the above procedure.

Terminal Keyboard

The Tektronix keyboard is used mainly to key in data. The RETURN key is used to transmit data to the computer, whether entered from the keyboard, crosshair, or tablet.

The screen CURSOR shows the position where keyed-in data will appear. Throughout the program, prompting for keyboard input will occur either after a displayed message or after the user has selected to modify a data value.

Prompting messages are in the form of a question, or a command; options are listed and the response must always be numeric with the exception of the analysis name.

The key-in of data may be requested for a single value or multiple values. Data is read in unformatted, so it is not necessary to include the decimal for whole numbers.

Multiple item requests may be keyed in by separating the individual items by one or more spaces or a comma. If RETURN is keyed before the list is complete, the program will not continue until all items have been entered and transmitted.

Single-valued data is transmitted after the RETURN key.

Corrections of data may be accomplished by backspacing and re-entering any time before the RETURN key is struck. After the RETURN key, the data has been transmitted and can only be modified later by editing.

SECTION III

DATA FILES

The user is provided with the optional use of two available disk data sets, identified as the SAVE file and the PRINT file.

MASTER SAVE FILE

Type

Unformatted.

Contents

Input and output data values for each saved solution.

Construction

The SAVE file is available following the successful solution of a joint problem. If, after the analysis results are displayed, the user elects to save the problem, all input and output data values are written to the SAVE file along with its identifying analysis NAME and type. Each instruction to save writes the solution at the end of the files data. Duplicate analysis NAMES are permitted, and 100 solutions may be written to the SAVE file before program limits are reached.

After the 100th solution has been written to the SAVE file, the following warning will be displayed:

MAX. SOLUTIONS ON SAVE FILE.

If the user attempts to add another solution, these messages will be displayed:

SAVE ABORTED.

MAX. SOLUTIONS ON SAVE FILE.

If additional solutions are to be saved, the user must either purge some of the existing solutions (ref. section VII), or exit the program and provide a different SAVE file to the program upon re-execution.

The user may use a previously constructed SAVE file. All existing data is retained, and new solutions may be added to the end. All solutions on the file are available for PRINT and CONSOLIDATION options (see sections VI and VII).

Usage

The SAVE file has two specific uses: 1) to provide basic input data to the analysis routines and, 2) to permit selective output of solutions subsequent to the analysis.

Many of the analysis routines in JOINT permit the user to select an analysis from the SAVE file as basic input. This basic data may then be modified to fit a new problem, which is generally less time consuming than keying in all the constraints from scratch.

Secondly, the user may desire to selectively output solutions stored on the SAVE file. The data is then written in formatted form to either the Tektronix terminal screen, or to a PRINT file for later disposition by the user. Reference section VI for selective output processing procedures.

PRINT FILE

Type

Formatted (ASA carriage control)

Content

Complete input and output data for each solution output.

Construction

The file is constructed by using the same WRITE statements that displayed the problem solution following its analysis. Therefore, except for the bonded stepped-lap joints which displays only a summary, the PRINT file will be a duplicate of the displayed output.

The PRINT file is made available to the user at two places in the program. First, after a problem has been analyzed and the solution displayed, the user is given options to write to the PRINT file, and to the SAVE file. Writing to the PRINT file at this time utilizes the solution input/output data stored in the computer. Second, if the user outputs the solution to the SAVE file, he may wait until a later time, enter the SELECTIVE OUTPUT PROCESSING mode, and select all those solutions on the SAVE file he wishes to be written to the PRINT file.

All data is written sequentially to the PRINT file, so the user may print at any time throughout the session.

CAUTION: If previously constructed PRINT file is input to the JOINT program, the old information will be lost if the file is used.

Usage

After exiting the JOINT program the PRINT file may be utilized for off-line hardcopy, or for on-line viewing:

Max. characters/line = 110

Max. lines/page = 64

Messages

If the user writes on the PRINT file during the session, the following informational message will be displayed after exiting from the program:

PRINT FILE HAS BEEN WRITTEN ON.

SECTION IV

PROGRAM EXECUTION

PROCEDURE

Figure 2 gives an example of a typical procedure for executing the JOINT program. Specification of the SAVE and PRINT files, and their local file names is at the user's discretion. In this example, a SAVE file is input from a previous session, and a permanent PRINT file is assigned.

If the user indicates that data exists on the SAVE file, the program reads the file and records the analysis names and types.

If the graphics tablet is not desired, the terminal screen crosshairs will be used for screen locations.

Figure 3 shows the basic program options, and EXIT messages.

ABNORMAL PROGRAM EXITS

System aborts generally will indicate that an illegal arithmetic operation has been attempted due to bad input data.

If the user wishes to immediately leave the program and enter the COMMAND mode, he may initiate an abort from the keyboard at any time.

After an abrormal exit from JOINT, rewind the files to avoid the possibility of losing data still in the computer buffers.

NOTE: If data is on the PRINT file, re-executing JOINT will rewind and write over the file, thereby destroying existing data.

```
                                                   COMMENTS

COMMAND- screen,132.                   set  screenlength to 132 char./line

COMMAND- attach,x,mkstape1.            a save file from a previous session.

 PF CYCLE NO. = 004
COMMAND- request,a,*pf.                permanent save file for this session.

COMMAND- request,b,*pf.                permanent print file for this session.

COMMAND- rewind,x,a

COMMAND- copy,x,a.                     copy file for use during this session.

COMMAND- attach,joint,                 JOINT program to be executed.

 PFN IS
 JOINT
 PF CYCLE NO. = 027
COMMAND- joint,a,b.                    request execution of JOINT program.
                                       local file A equivalenced to TAPE1 default.
                                       local file B equivalenced to TAPE2 default.


DOES SAVE FILE CONTAIN DATA? (1=YES, 0=NO): 1

  16 SOLUTIONS ON SAVE FILE.

IS GRAPHICS TABLET TO BE USED FOR SCREEN LOCATIONS? (1=YES, 0=NO): 0
```

Figure 2. Joint Execution Procedure

```
                    COMPOSITE JOINT DESIGN PROGRAM

         ---->      CODE    OPTION
                      1 *   ANALYZE JOINT
                      2 *   SELECTIVE OUTPUT OF SOLUTIONS FROM SAVE FILE
                      3 *   CONSOLIDATE SOLUTIONS ON SAVE FILE
                      4 *   EXIT
ENTER CODE: 4


CATALOG SAVE AND PRINT FILES AS DESIRED.
 SAVE FILE CONTAINS  21 SOLUTIONS.
 PRINT FILE HAS BEEN WRITTEN ON.
     STOP
     38.039 CP SECONDS EXECUTION TIME
COMMAND-
```

Figure 3. Main Menu and Exit Messages

SECTION V

COMPOSITE JOINT ANALYSIS

The selection of Option 1 in Figure 3 will display the page in Figure 4 which lists all the analysis options available to the user. Codes 1-4 identify the bolted joint analysis routines, while codes 5-9 identify the bonded joint analysis routines.

The user may select and process any one of the nine joints, and will remain in that mode until returning to Analysis Options to select a different option.

All analysis options have an editing feature which allows the user to make corrections or modifications to the input data. Depending on the quantity of data required for the different option codes, there are 3 editing features used:

1. COMPLETE RE-INPUT: Codes 1, 2, 3
2. DATA GROUP RE-INPUT: Codes 4 and 8
3. INDIVIDUAL MODIFICATION BOXES: Codes 5, 6, 7, 9

For analysis codes 4-9, the user is given the opportunity to select the input data of a solution on the SAVE file to be read in as basic input data for the current analysis. The user may then modify particular input data values to represent the current problem.

TYPICAL ANALYSIS PROCEDURE

This section explains the typical procedures used to analyze a problem. Refer to figures 4 through 8.

Enter Numeric Code

Choose one of the 9 codes corresponding to the desired joint type. A zero will return the user to the main menu (Figure 3).

```
                    ANALYSIS OPTIONS

                                   JOINT CODE
        CLASS                     BOLT    BOND

  STANDARD DOUBLE-LAP              1       5
  UNSUPPORTED SINGLE-LAP           2       6
  SUPPORTED SINGLE-LAP             3       7
  STEPPED-LAP                      4       8
  SCARFED                                  9

ENTER NUMERIC CODE (0 = RETURN): 5

INPUT DATA FROM A SOLUTION ON SAVE FILE? (1=YES, 0=NO): 1
```

Figure 4. Analysis Options

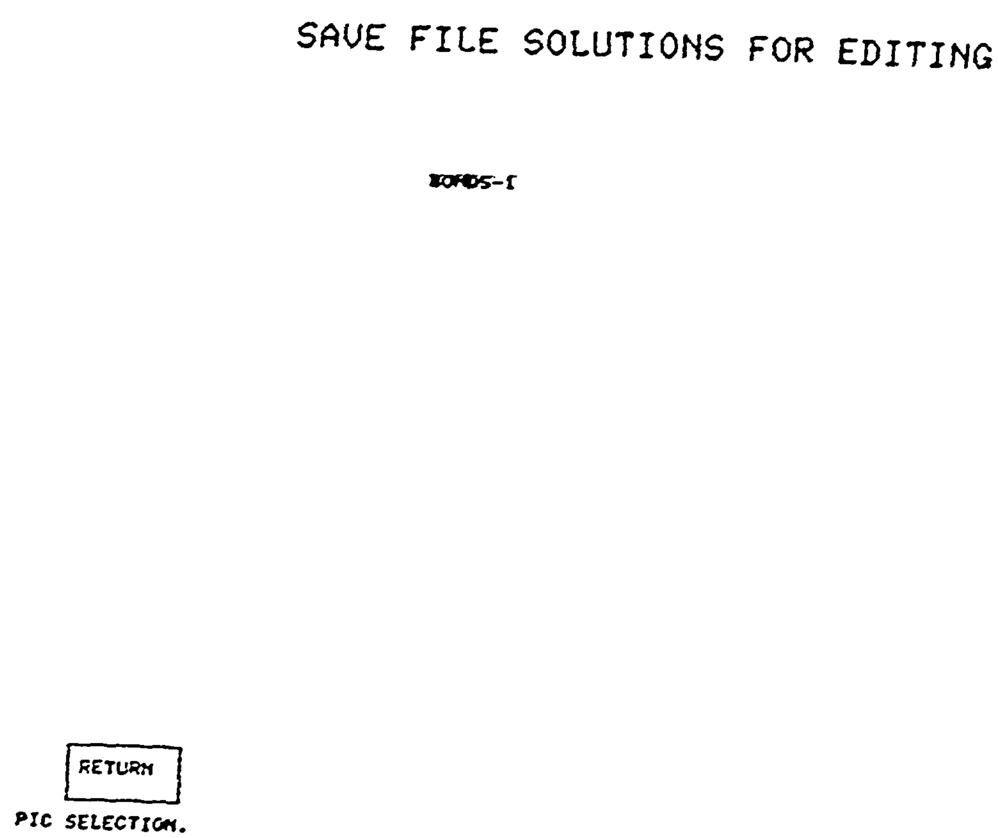
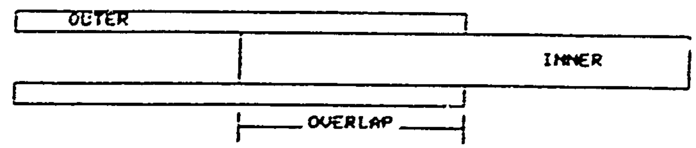


Figure 5. Save File Solutions Available For Editing

```
ANALYSIS BONDS-1  INPUT AND AVAILABLE FOR EDITING.
OPTIONS:  0 - RETURN TO ANALYSIS OPTIONS
          1 - INPUT ALL CONSTRAINT DATA
          2 - EDIT AVAILABLE DATA

ENTER OPTION NUMBER: 2


ENTER LOAD TYPE (1, 0, -1): 1

   1.02 CP SECONDS ELAPSED.
ENTER ANALYSIS NAME: bond5-3
```

Figure 6. Input Options and Analysis Name

BONDED -- STANDARD DOUBLE-LAP JOINT
ANALYSIS NAME = BOND5-2



---> INPUT JOINT CONSTRAINTS:	VALUE	MOD.
☐ LOAD TYPE (1, 0, -1)	1	
☐ LOAD (LB./IN.)	15000.	22000
☐ OVERLAP (IN.)	5.000	6.5

---> INPUT ADHESIVE PROPERTIES:	VALUE	MOD.
☐ MAX. SHEAR STRAIN	1.10	
☐ BOND THICKNESS	.0050	
☐ OPERATING TEMP.	300.	
☐ CURE TEMP.	400.	
☐ PEEL MODULUS	0.	500000

	VALUE	MOD.
☐ ELASTIC SHEAR STRENGTH	5000.	
☐ LINEAR ELASTIC MODULUS	60000.	
☐ EL.-PL. SHEAR STRENGTH	7000.	
☐ NON-LINEAR EL. MODULUS	60000.	
☐ PEEL STRENGTH	0.	10000

---> INPUT ADHEREND PROPERTIES:

INNER	VALUE	MOD.
☐ THICKNESS (IN.)	.30	
☐ YOUNG'S MODULUS	.100E+08	
☐ POISSON'S RATIO	.30	
☐ THERMAL COEFF.	.000013	
☐ YIELD STRENGTH	40000.	65000
☐ TRANSV. MODULUS	.0	.1e+8
☐ TRANSV. STRENGTH	0.	50000

OUTER	VALUE	MOD.
☐ THICKNESS (IN.)	.40	
☐ YOUNG'S MODULUS	.100E+08	
☐ POISSON'S RATIO	.30	
☐ THERMAL COEFF.	.000006	
☐ YIELD STRENGTH	40000.	0
☐ TRANSV. MODULUS	.0	
☐ TRANSV. STRENGTH	0.	

RETURN EXECUTE RE-DISPLAY

Figure 7. Typical Analysis Input Display

```
                    BONDED -- STANDARD DOUBLE-LAP JOINT
                        ANALYSIS NAME - BONDS-2

BASIC DATA:  LOAD TYPE      -  1 (TENSION)
             LOAD (LB/IN) - 22000.
             OVERLAP (IN) -  6.500

ADHESIVE PROPERTIES:
         MAX. SHEAR STRAIN            1.10      ELASTIC SHEAR STRENGTH (PSI)    5000.
         BOND THICKNESS    (IN.)      .005      LINEAR ELASTIC MODULUS (PSI)   60000.
         OPERATING TEMP.   (F.)       300.      EL.-PL. SHEAR STRENGTH (PSI)    7000.
         CURE TEMP.        (F.)       400.      NON-LINEAR EL. MODULUS (PSI)   60000.
         PEEL MODULUS      (PSI)      500000.   PEEL STRENGTH          (PSI)   10000.

ADHEREND PROPERTIES:                  (INNER)   (OUTER)
         THICKNESS         (IN.)      .30       .40
         YOUNG'S MODULUS   (PSI)      .100E+08  .100E+08
         POISSON'S RATIO              .30       .30
         THERMAL COEFF.               .0000130  .0000060
         YIELD STRENGTH    (PSI)      65000.    65000.
         TRANSV. MODULUS   (PSI)      .100E+08  .100E+08
         TRANSV. STRENGTH  (PSI)      50000.    50000.

JOINT ANALYSIS:
         OPTIMUM OVERLAP (IN.) -  3.20

         ADHESIVE SHEAR TYPE-     STRENGTH(LB/IN)   STRAIN
            ELASTIC-PLASTIC          26627.
            LINEAR ELASTIC            5455.          .083
            NON-LINEAR ELASTIC        7904.          .117
            PLASTIC                                  .983

         ADHERENDS-  INNER           19500.
                     OUTER           52000.

         LIMIT DUE TO
         ADHESIVE PEEL OR
         INTERLAMINAR TENSION-       21816.

STRENGTH COMPUTATION
  OVERLAP (IN.) 6.50         BOND SHEAR STRENGTH (LB./IN.) 26627.
  BOND MORE CRITICAL WHERE INNER ADHEREND EXTENDS FROM JOINT

JOINT STRENGTH LESS THAN APPLIED LOAD

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *
```

Figure 8. Output Display for Figure 7.

Optional Input From The Save File

If the SAVE file contains solutions with a type the same as the joint type selected, the user will be given the option to select one for editing. Otherwise the message,

NO SOLUTIONS AVAILABLE ON SAVE FILE FOR THIS CODE

will be displayed.

If the user selects the SAVE file, a page similar to Figure 5 will be displayed, listing all the solutions on the SAVE file of the same analysis type (joint code). Using the crosshairs or tablet the user is requested to pick the solution name that contains the basic input data desired. If a name is detected, JOINT will search the file and read the data for that solution, even if duplicate names exist on the SAVE file.

Selecting RETURN will exit this mode and continue without data from the SAVE file.

User Input Options

Figure 6 shows the next sequence of instructions. If a SAVE file solution has been selected, the first line confirms to the user that the appropriate analysis has been read and available for editing. The user is then requested to enter an input option.

1. The user may not wish to enter the analysis routine, and this option will RETURN to Analysis Option , Figure 4.

2. Even though edit data may be available, this option allows the user to input all data from scratch.

3. This option permits direct editing of the existing data whether from the previous analysis or from the SAVE file.

Special Input Data

Special Data refers to data required by the bonded joint options:

- Double-lap and Supported Single-lap Joints:

  ENTER LOAD TYPE (1, 0, -1)

  1 = Tension

  0 = In-plane shear

  -1 = Compression

- Stepped-lap Option To Analyze a Doubler

- Scarf Joint Option To Use 1 or 2 Bond Surfaces

Analysis Name

The analysis NAME is from one to eight hollerith characters, including blanks. This name identifies the analysis and is requested before each analysis routine is entered. The user must keep track of any duplicate names used.

Example Joint Problem Input

Figure 7 illustrates the typical components of all analysis routines.

Title and Picture

The title includes the type of joint analysis, and the user assigned name.

The picture is non-dimensional and only represents the joint type.

Input Constraint Data

Whether inputing all items or editing existing data, the data items required are listed and the user is prompted for their values.

Pre-Execution Options

When all input data has been entered, the user may choose from the following pre-execution options.

RE-INPUT - Re-input all or groups of data

RE-DISPLAY - All bonded joints, except the stepped lap. Re-displays the screen with any modified and default values.

EXECUTE - Clears the screen, analyzes the input data, and displays the solution.

RETURN - Clears the screen and returns to analysis option (Figure 4)

Post-Processing Options

Figure 8 shows the solution displayed for the input in Figure 7, and includes the input and output data values. After the successful solution the user may select the following post-processing options.

Output To Print File

Writes the complete input and output data to the PRINT file.

Copy To Master Save File

Copies all the input and output data to the master SAVE file.

Re-Analyze

Clears the screen and allows the user to remain within the existing joint type routines for analyzing a new problem.

Return

Clears the screen and returns to Analysis Options (Figure 4).

BOLTED DOUBLE AND SINGLE-LAP JOINTS (CODES 1, 2, 3)

This option covers the analysis for bolted double-lap, supported single-lap, and unsupported single-lap joints. There is no editing capability due to the small number of parameters required.

The effective material thickness parameter refers to the thickness of either laminate. For the double-lap joint, each outer laminate is one-half the inner thickness for a total joint thickness of 2t.

Each of the single-lap laminates have the same thickness, t. This provides for a balanced joint.

Since the input and output displays are identical for all three joint types except for the header, the double-lap will be given as representative of the format and layout.

Input Data

Figure 9 shows the input display for a typical bolted joint. The program uses the input values of P and N to allow the user to either optimize or analyze the problem.

For an optimized joint, N = 0 and the joint load, P, is used to determine the optimum values for T, D, W, and N, with minimum joint weight as the criteria.

To analyze a joint, N ≠ 0 and the user is prompted for T, D, and W. If P = 0, the allowable joint load is computed; if P ≠ 0, the associated margins of safety for each bolt row are relevant.

Since the user may desire to specify a safety factor for tension failures, FS is provided to scale down the ultimate tension allowable (FTU = FTU/FS). For an optimum design (N = 0), the user may force a bearing failure by specifying FS = 0; For analysis of a design (N ≠ 0), FS = 0 defaults to FS = 1.

Defaults

If N = 0 and P = 0, N is set to 1 and the user is prompted for T, D, & W.

If FS = 0 for an analysis, N defaults to 1.

Editing

Selecting the RE-INPUT option will prompt the user to re-input all data values. Since there are so few, it would take more of the user's time to to select and edit specific values.

Output Data

Figure 10 shows the output display for the input in Figure 9.

The joint weight is calculated for all problems along with the bolt row strengths. The percent of load transferred between plates by each bolt row and its associated margin of safety is displayed. The failure modes possible are tension, bearing, bolt shear and tear-out.

Re-analysis Procedure

After selecting the re-analysis option, the page is cleared and the analysis NAME is requested. The page is then cleared again, and all input data requested. No individual editing is available.

CP Times

1 to 30 seconds, with optimization (N = 0) taking the longest.

Examples

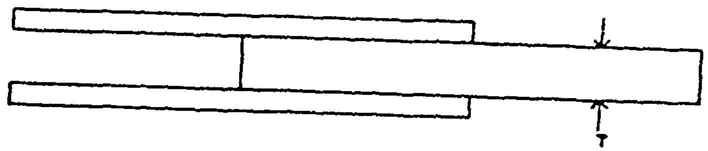
Three different types of analyses available to the user: (1) optimization (2) analysis, and (3) margins of safety only.

(1) Figures 11 (a) and 11 (b) determine the optimum joint designs for a required joint load of 14,000 lb/in.

(2) Figures 12 (a) and 12 (b) input the joint designs from #1 above to determine the maximum allowable joint load, which should be the 14,000 lb/in. input for #1.

(3) Figures 13 (a) and 13 (b) show all input parameters used to calculate the joint weight for the input design, and the margins of safety for the input applied load.

BOLTED -- STANDARD DOUBLE LAP JOINT
ANALYSIS NAME = BOLT1-9



DESCRIPTION OF INPUT CONSTRAINTS

P = JOINT LOAD (LB./IN.)

FS = JOINT M.S. FACTOR FOR TENSION

TEMP = JOINT TEMP. (DEG. F.)

MATL = % 0-DEGREE GRAPHITE PLIES (25 OR 37)

BOLT = 1 (TITANIUM)
= 2 (STEEL)

N = NO. OF BOLT ROWS

ENTER THE FOLLOWING IF N > 0

T = MATERIAL THICKNESS
D = BOLT DIAMETER
W = WIDTHWISE BOLT SPACING

ENTER VALUES FOR P, FS, TEMP, MATL, BOLT, N: 0 1.25 50 25 1 2

ENTER VALUES FOR T, D, W: .3 .25 2

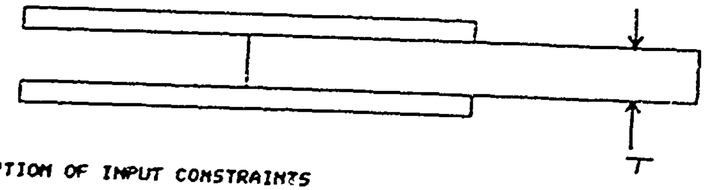
RETURN EXECUTE RE-INPUT

Figure 9. Bolted Double-Lap Input (Analysis)

```
BALANCED BOLTED DOUBLE-LAP COMPOSITE JOINT ANALYSIS PRINTOUT
                  ANALYSIS NAME - BOLT1-1

CODE     INPUT DATA:                          VALUE

NX          JOINT LOAD  (LB./IN.)               0.
FS          JOINT M.S. TENSION FACTOR         1.25
TEMP        JOINT TEMP  (DEG. F.)              50.
MATL        % 0-DEGREE GRAPHITE PLIES           25
BOLT        BOLT TYPE                         1 (TITANIUM)
N           NO. OF BOLT ROWS                    2

T           MATL  THICKNESS  (IN.)            .300
D           BOLT DIAMETER    (IN.)            .250
W           BOLT SPACING     (IN.)           2.000
            W/D RATIO                        8.000
            G-D ROW SPACING                  1.500


         OUTPUT DATA:

           JOINT WEIGHT    (LB/IN)           .0858
           MAX. JOINT LOAD (LB/IN)           4879.

              SUMMARY OF BOLT ROW STRENGTHS

         BOLT    % OF LOAD    MARGIN OF    FAILURE
         ROW    TRANSFERRED    SAFETY       MODE

          1         50           .43       TENSION
          2         50          0.00       TENSION

 *  CUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *

                      (COMPLETE)



  3.236 CP SECONDS ELAPSED.
 ENTER ANALYSIS NAME: bolt1-11
```

Figure 10.   Bolted Double-Lap Output (Analysis)

BOLTED -- STANDARD DOUBLE LAP JOINT
ANALYSIS NAME = BOLT1-11



DESCRIPTION OF INPUT CONSTRAINTS

P - JOINT MEMBRANE LOAD (LBS/IN)

FS - JOINT M.S. FACTOR FOR TENSION

TEMP - JOINT TEMP. (DEG. F.)

MATL - % 0-DEGREE GRAPHITE PLIES (25 OR 37)

BOLT - 1 (TITANIUM)

- 2 (STEEL)

N - NO. OF BOLT ROWS

ENTER THE FOLLOWING IF N > 0

T - MATERIAL THICKNESS
D - BOLT DIAMETER
W - WIDTHWISE BOLT SPACING

ENTER VALUES FOR P, FS, TEMP, MATL, BOLT, N: 14000 1.2 0 37 2 0

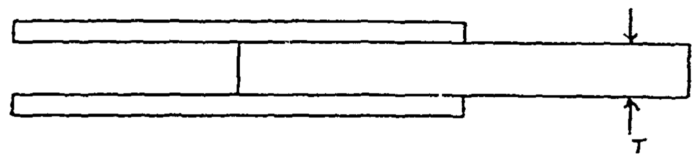
RETURN | EXECUTE | RE-INPUT

Figure 11(a) Bolted Double-Lap Input (Optimization)

```
BALANCED BOLTED DOUBLE-LAP COMPOSITE JOINT ANALYSIS PRINTOUT
                ANALYSIS NAME - BOLT1-11

CODE      INPUT DATA:                         VALUE

MX          JOINT LOAD  (LB./IN.)            14000.
FS          JOINT M.S. TENSION FACTOR          1.20
TEMP        JOINT TEMP  (DEG. F.)               0.
MATL        % 0-DEGREE GRAPHITE PLIES           37
BOLT        BOLT TYPE                       2 (STEEL)
N           NO. OF BOLT ROWS                     1

T           MATL  THICKNESS  (IN.)            .654
D           BOLT DIAMETER    (IN.)            .688
W           BOLT SPACING     (IN.)           2.283
            W/D RATIO                        3.321
            G-D ROW SPACING                  4.125


          OUTPUT DATA:

            JOINT WEIGHT     (LB/IN)         .3707

               SUMMARY OF BOLT ROW STRENGTHS

          BOLT    % OF LOAD     MARGIN OF    FAILURE
          ROW     TRANSFERRED    SAFETY       MODE

           1         100          -.00       TENSION

NO JOINT DESIGN BASED ON BEARING FAILURE IS POSSIBLE

* OUTPUT TO PRINT FILE *  OUTPUT TO SAVE FILE   * RE-ANALYZE * RETURN *




 13.126 CP SECONDS ELAPSED.
ENTER ANALYSIS NAME: bolt1-12
```

Figure 11(b). Bolted Double-Lap Output (Optimization)

BOLTED -- STANDARD DOUBLE LAP JOINT
ANALYSIS NAME = BOLT1-12



DESCRIPTION OF INPUT CONSTRAINTS

P - JOINT MEMBRANE LOAD (LBS/IN)

FS - JOINT M.S. FACTOR FOR TENSION

TEMP - JOINT TEMP. (DEG. F.)

MATL - % 0-DEGREE GRAPHITE PLIES (25 OR 37)

BOLT - 1 (TITANIUM)

- 2 (STEEL)

N - NO. OF BOLT ROWS

ENTER THE FOLLOWING IF N > 0

T - MATERIAL THICKNESS
D - BOLT DIAMETER
W - WIDTHWISE BOLT SPACING

ENTER VALUES FOR P, FS, TEMP, MATL, BOLT, N: 0 1.2 0 37 2 1

ENTER VALUES FOR T, D, W: .654 .688 2.283

RETURN

EXECUTE

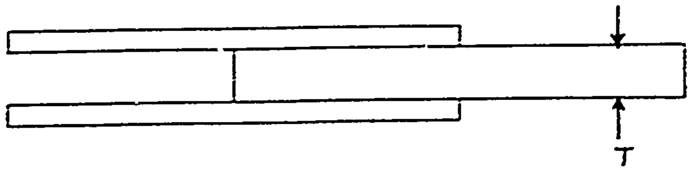
RE-INPUT

Figure 12(a). Bolted Double-Lap Input

```
        BALANCED BOLTED DOUBLE-LAP COMPOSITE JOINT ANALYSIS PRINTOUT
                         ANALYSIS NAME - BOLT1-12

CODE      INPUT DATA:                              VALUE

NX          JOINT LOAD  (LB./IN.)                     0.
FS          JOINT M.S. TENSION FACTOR              1.20
TEMP        JOINT TEMP  (DEG. F.)                     0.
MATL        % 0-DEGREE GRAPHITE PLIES                37
BOLT        BOLT TYPE                         2 (STEEL)
N           NO. OF BOLT ROWS                          1

T           MATL  THICKNESS   (IN.)                .654
D           BOLT DIAMETER     (IN.)                .688
U           BOLT SPACING      (IN.)               2.283
            U/D RATIO                             3.318
            6-D ROW SPACING                       4.128


          OUTPUT DATA:

            JOINT WEIGHT     (LB/IN)              .3712
            MAX. JOINT LOAD (LB/IN)              14004.

               SUMMARY OF BOLT ROW STRENGTHS

          BOLT    % OF LOAD      MARGIN OF     FAILURE
          ROW     TRANSFERRED     SAFETY        MODE

           1         100           0.00        TENSION

NO JOINT DESIGN BASED ON BEARING FAILURE IS POSSIBLE

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE    *  RE-ANALYZE  *  RETURN  *



13.206 CP SECONDS ELAPSED.
ENTER ANALYSIS NAME: bolt1-13
```

Figure 12(b). Bolted Double-Lap Output

BOLTED -- STANDARD DOUBLE LAP JOINT
ANALYSIS NAME = BOLT1-13



DESCRIPTION OF INPUT CONSTRAINTS

P = JOINT MEMBRANE LOAD (LBS/IN)

FS = JOINT M.S. FACTOR FOR TENSION

TEMP = JOINT TEMP. (DEG. F.)

MATL = % 0-DEGREE GRAPHITE PLIES (25 OR 37)

BOLT = 1 (TITANIUM)

= 2 (STEEL)

N = NO. OF BOLT ROWS

ENTER THE FOLLOWING IF N > 0

T = MATERIAL THICKNESS
D = BOLT DIAMETER
W = WIDTHWISE BOLT SPACING

ENTER VALUES FOR P, FS, TEMP, MATL, BOLT, N: 10000 1 0 25 1 1

ENTER VALUES FOR T, D, W: .5 .75 2

RETURN | EXECUTE | RE-INPUT

Figure 13(a). Bolted Double-Lap Input ($P \neq 0$, $N \neq 0$)

```
BALANCED BOLTED DOUBLE-LAP COMPOSITE JOINT ANALYSIS PRINTOUT
                 ANALYSIS NAME - BOLT1-13

CODE      INPUT DATA:                             VALUE

NX           JOINT LOAD  (LB./IN.)               10000.
FS           JOINT M.S. TENSION FACTOR             1.00
TEMP         JOINT TEMP  (DEG. F.)                   0.
MATL         % 0-DEGREE GRAPHITE PLIES               25
BOLT         BOLT TYPE                            1 (TITANIUM)
N            NO. OF BOLT ROWS                         1

T            MATL. THICKNESS   (IN.)               .500
D            BOLT DIAMETER     (IN.)               .750
W            BOLT SPACING      (IN.)              2.000
             W/D RATIO                            2.667
             E-D ROW SPACING                      4.500


          OUTPUT DATA:

             JOINT WEIGHT     (LB/IN)             .2559

                SUMMARY OF BOLT ROW STRENGTHS

          BOLT    % OF LOAD      MARGIN OF     FAILURE
          ROW     TRANSFERRED     SAFETY        MODE

           1         100            .20        TENSION

NO JOINT DESIGN BASED ON BEARING FAILURE IS POSSIBLE

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *
```

Figure 13(b). Bolted Double-Lap Output (Margins and Weight)

BOLTED STEPPED-LAP JOINT (CODE #4)

This has only an analysis capability to determine the margins of safety for the different steps from the proposed design and its applied load.

Input Data

Figure 14 (a) shows the input display of a typical problem.

The joint tension factor is applied as a factor of safety to rows that have a tension failure mode.

After the basic data has been entered, the user is prompted for the data describing each bolt row.

Defaults (entering zero):

bolt material = titanium

graphite patterns = 25

Editing

Editing of data may be done by selecting the RE-INPUT option after key-in, or after selecting a solution from the SAVE file.

Figure 14 (b) shows a typical procedure for editing.

Output Data

After executing the analysis routines, the solution will be displayed. Figure 14 (c) shows the output for the example input of 14 (a). The output contains the percent of load transferred, the failure mode, and margin of safety for each bolt row.

Re-Analysis Procedure

Figure 14 (d) shows the user how to re-analyze a stepped-lap problem, utilizing data from the previous problem rather than the SAVE file with figure 14 (e) showing the resulting output after execution.

CP Times - approximately 1 second.

Examples:

Figure 14 (a) - Input all data items.

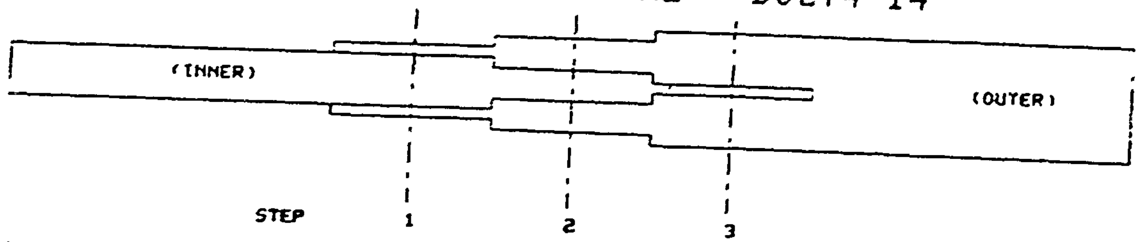
(b) - Edit input data.

(c) - Output.

(d) - Re-analyze previous problem.

(e) - Output.

BOLTED -- STEPPED-LAP JOINT ANALYSIS
ANALYSIS NAME = BOLT4-14



---> BASIC INPUT DATA:

1) NO. OF BOLT ROWS (STEPS)
2) JOINT LOAD (LB./IN.)
3) JOINT TEMP (DEG. F.)
4) JOINT TENSION FACTOR
5) BOLT MATERIAL (1=TITANIUM, 2=STEEL)
6) % 0-DEGREE PLIES OF INNER GRAPHITE PATTERN (25 OR 37)
7) % 0-DEGREE PLIES OF OUTER GRAPHITE PATTERN (25 OR 37)

---> BOLT ROW DATA:

L - STEP LENGTH (LAND)
D - BOLT DIAMETER
SP - BOLT SPACING
TI - INNER MATERIAL THICKNESS
TO - OUTER MATERIAL THICKNESS

ENTER 7 BASIC DATA VALUES: 3 20000 30 1.25 1 25 37

ENTER L, D, SP, TI, TO FOR EACH STEP.

STEP 1 : 2 .375 2.5 .4 .2

STEP 2 : 2 .25 3 .3 .4

STEP 3 : 2 .375 2.5 .2 .8

RETURN

EXECUTE

RE-INPUT

Figure 14(a). Bolted Stepped-Lap Input

```
VIEW EXISTING INPUT DATA? (0=NO, 1=YES): 1


BASIC INPUT DATA:

     NO. OF BOLT ROWS          = 3
     JOINT LOAD (LB./IN.)      = 20000.
     JOINT TEMP.(DEG. F.)      = 30.
     JOINT TENSION FACTOR      = 1.25
     BOLT MATERIAL             = 1 (TITANIUM)
     25 X 0-DEGREE PLIES FOR INNER GRAPHITE PATTERN
     37 X 0-DEGREE PLIES FOR OUTER GRAPHITE PATTERN

BOLT ROW DATA:

   STEP    STEP     BOLT    BOLT     BOLT  X GRAPHITE THICKNESS X
    NO.   LENGTH    DIAM.  SPACING   W/D      INNER     OUTER

    1      2.00     .375    2.50     0.       .400      .200
    2      2.00     .250    3.00     0.       .300      .400
    3      2.00     .375    2.50     0.       .200      .300

UPDATE BASIC DATA? (0=NO, 1=YES): 0

UPDATE STEP DATA? (0=NO, 1=YES): 1

ENTER STEP NO. (0 = END): 2

ENTER L, D, SP, TI, TO FOR STEP 2
2 .25 3 .3 .5

ENTER STEP NO. (0 = END): 0
```

RETURN | EXECUTE | RE-INPUT

Figure 14(b). Bolted Stepped-Lap Editing

```
        BOLTED -- STEPPED-LAP JOINT ANALYSIS
             ANALYSIS NAME - BOLT4-14

BASIC INPUT DATA:

     NO. OF BOLT ROWS        -  3
     JOINT LOAD (LB./IN.)    -  20600.
     JOINT TEMP.(DEG. F.)    -  30.
     JOINT TENSION FACTOR    - 1.25
     BOLT MATERIAL           -  1 (TITANIUM)
     25 % 0-DEGREE PLIES FOR INNER GRAPHITE PATTERN
     37 % 0-DEGREE PLIES FOR OUTER GRAPHITE PATTERN

BOLT ROW DATA:

   STEP     STEP       BOLT      BOLT       BOLT  * GRAPHITE THICKNESS *
   NO.      LENGTH     DIAM.     SPACING    W/D       INNER      OUTER

    1        2.00      .375      2.50        7.       .400       .200
    2        2.00      .250      3.00       12.       .300       .500
    3        2.00      .375      2.50        7.       .200       .800

SUMMARY OF BOLT ROW STRENGTHS

     BOLTS - % OF LOAD TRANSFERRED BY BOLTS
     INNER - % OF LOAD RETAINED BY INNER PLATE
     OUTER - % OF LOAD RETAINED BY OUTER PLATE
     M.S.  - MARGIN OF SAFETY

   ROW      BOLT     INNER     OUTER       M.S.       FAILURE MODE

    1        48        52         0       -.681       OUTER TENSION
    2        20        32        48       -.512       OUTER TENSION
    3        32         0        68       -.442       INNER BEARING

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE    *  RE-ANALYZE  *  RETURN  *
```

Figure 14(c). Bolted Stepped-Lap Output

```
INPUT DATA FROM A SOLUTION ON SAVE FILE? (1-YES, 0-NO): 0

MODIFY EXISTING INPUT DATA? (1-YES, 0-ALL NEW): 1

  1.129 CP SECONDS ELAPSED.
ENTER ANALYSIS NAME: bolt4-d

VIEW EXISTING INPUT DATA? (0-NO, 1-YES): 1


BASIC INPUT DATA:

     NO. OF BOLT ROWS       =  3
     JOINT LOAD (LB./IN.) =  20000.
     JOINT TEMP.(DEG. F.) =  30.
     JOINT TENSION FACTOR = 1.25
     BOLT MATERIAL         = 1 (TITANIUM)
     25 % 0-DEGREE PLIES FOR INNER GRAPHITE PATTERN
     37 % 0-DEGREE PLIES FOR OUTER GRAPHITE PATTERN

BOLT ROW DATA:

   STEP      STEP       BOLT      BOLT       BOLT  % GRAPHITE THICKNESS %
    NO.     LENGTH      DIAM.    SPACING     W/D       INNER      OUTER

    1        2.00       .375      2.50        7.       .400       .200
    2        2.00       .250      3.00       12.       .300       .500
    3        2.00       .375      2.50        7.       .200       .800

UPDATE BASIC DATA? (0-NO, 1-YES): 1

ENTER 7 BASIC DATA VALUES: 2 10000 30 1.25 2 37 25

ENTER L, D, SP, TI, TO FOR EACH STEP.

STEP  1 : 2 .375 2.5 .6 .2

STEP  2 : 3 .25 3 .4 .6
```

RETURN | EXECUTE | RE-INPUT

Figure 14(d). Bolted Stepped-Lap Modifications

```
          BOLTED -- STEPPED-LAP JOINT ANALYSIS
               ANALYSIS NAME - BOLT4-D

  BASIC INPUT DATA:

       NO. OF BOLT ROWS        -  2
       JOINT LOAD (LB./IN.)  -  10000.
       JOINT TEMP.(DEG. F.)  -  30.
       JOINT TENSION FACTOR - 1.25
       BOLT MATERIAL           - 2 (STEEL)
       37 X 0-DEGREE PLIES FOR INNER GRAPHITE PATTERN
       25 X 0-DEGREE PLIES FOR OUTER GRAPHITE PATTERN

  BOLT ROW DATA:

    STEP     STEP       BOLT      BOLT      BOLT  * GRAPHITE THICKNESS *
    NO.     LENGTH      DIAM.    SPACING     W/D       INNER      OUTER

     1       2.00       .375      2.50       7.        .600       .200
     2       3.00       .250      3.00      12.        .400       .600

  SUMMARY OF BOLT ROW STRENGTHS

    BOLTS - % OF LOAD TRANSFERRED BY BOLTS
    INNER - % OF LOAD RETAINED BY INNER PLATE
    OUTER - % OF LOAD RETAINED BY OUTER PLATE
    M.S.  - MARGIN OF SAFETY

    ROW    BOLT    INNER    OUTER     M.S.      FAILURE MODE

     1      63      37        0      -.500      OUTER TENSION
     2      37       0       63      -.443      INNER TENSION

 *  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *
```

Figure 14(e). Bolted Stepped-Lap Output

BONDED DOUBLE-LAP JOINT (CODE 5) AND
BONDED SUPPORTED SINGLE-LAP JOINT (CODE 7)

This subsection covers both the use of the bonded double-lap and supported single-lap joints. The same routines are used, being differentiated by a factor that accounts for the additional outer adherend and bond surface of the double-lap joint.

Full editing of all input parameters is available, and the user may select a solution on the SAVE file to supply the input for editing.

If the user edits existing data, whether from the SAVE file or a previous solution, the load type must be specified (1 = tension, 0 = in-plane shear, -1 = compression), for appropriate input parameters to be requested. After entering the analysis name, all available input data will be displayed and the edit mode entered.

Input Data

Figure 15 (a) and 15 (b) shows a typical example of a double-lap problem to analyze a tensile load from scratch. If the load is not tensile, the peel and transverse properties are not required.

When inputting all constraints from scratch, the screen will display each of the three groups of constraints (basic, adhesive, and adherend), then prompt the user for individual items. If the user changes the load type from tensile (load type = 1), the peel and transverse items will remain displayed but will not be used during execution.

Defaults: (entering a zero)

LOAD = 0: Joint strength calculated.

OVERLAP = 0: Optimum overlap used.

BOND THICKNESS = 0: .005 used.

OUTER ADHEREND PROPERTIES: Inner properties used.

(Except THERMAL COEFF. where zero is valid.)

Editing

After all constraints have been input, boxes are drawn next to each of the items. The user may then use the crosshair (or tablet) to select any item for modification. After transmitting the proper location, the cursor will appear under the MOD. column as a prompt for data key-in [see Figure 15 (b)].

At any time the user may exit the edit mode by selecting RETURN, EXECUTE, or RE-DISPLAY.

RE-DISPLAY will clear the screen and re-display all constraints by placing any MOD. or default item into the VALUE column. This is mainly a cleanup feature, useful any time the user desires to review all input data values.

Output Data

Figure 15 (c) shows the output following execution of the problem described in Figure 15 (b). This shows the maximum amount of output possible for this type of joint.

The joint analysis data is always given for a solution, which includes the optimum overlap length. Peel is only given for tensile loadings.

If LOAD $\neq$ 0, a stress analysis is computed on either the optimum overlap or the specified overlap to determine the adhesive shear stress and/or strain.

If OVERLAP $\neq$ 0, the bond shear strength is computed, along with its critical location.

Re-analysis

When RE-ANALYZE is selected after the output display, the screen is cleared and the user goes through the same procedure as before [see Figure 15 (d)]. However, regardless of whether or not the user has saved the solution, the user has the input data available in the computer for editing (until a different joint code is selected). The user may select a solution from the SAVE file for editing. The special data requested is the LOAD TYPE (1 = tension, 0 = in-plane shear, -1 = compression).

CP Times - Approximately 1 second

Examples

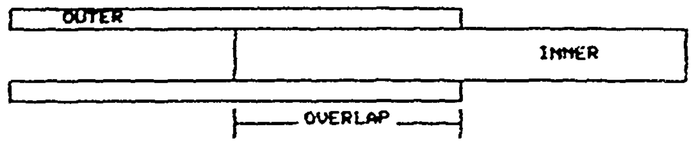
Figure 15 a) thru f) shows a succession of pages covering two problems. The use of the SAVE file is reference earlier in this section under Operational Input from Save File.

Figure	
15 (a)	° Option 5 selection ° Do not use SAVE file
15 (b)	° Input data for double-lap joint ° Tensile load of 30,000 lb/in. ° Overlap = 3.0 inch ° Utilize all defaults ° Modify values ° For example of re-display, see Figure 15 (e)
15 (c)	° Output example for Figure 15 (b) ° Save ° Print ° Re-Analyze
15 (d)	° Modify previous input data ° Compression
15 (e)	° Display of Figure 15 (b) data ° Modify values
15 (f)	° Output of Figure 15 (e) execution

```
                 ANALYSIS OPTIONS

                                 JOINT CODE
     CLASS                      BOLT    BOND

 STANDARD DOUBLE-LAP             1        5
 UNSUPPORTED SINGLE-LAP          2        6
 SUPPORTED SINGLE-LAP            3        7
 STEPPED-LAP                     4        8
 SCARFED                                  9

ENTER NUMERIC CODE (0 = RETURN): 5

INPUT DATA FROM A SOLUTION ON SAVE FILE? (1=YES, 0=NO): 0

OPTIONS:  0 = RETURN TO ANALYSIS OPTIONS
          1 = INPUT ALL CONSTRAINT DATA

ENTER OPTION NUMBER: 1

 17.481 CP SECONDS ELAPSED.
ENTER ANALYSIS NAME: bond5-15
```

Figure 15(a). Bonded Double-Lap Selection

BONDED -- STANDARD DOUBLE-LAP JOINT
ANALYSIS NAME = BOND5-15



---> INPUT JOINT CONSTRAINTS:	VALUE	MOD.
☐ LOAD TYPE (1, 0, -1)	1	
☐ LOAD (LB./IN.)	12000	
☐ OVERLAP (IN.)	3	

---> INPUT ADHESIVE PROPERTIES:

	VALUE	MOD.		VALUE	MOD.
☐ MAX. SHEAR STRAIN	1.5		☐ ELASTIC SHEAR STRENGTH	4500	
☐ BOND THICKNESS	0		☐ LINEAR ELASTIC MODULUS	70000	
☐ OPERATING TEMP.	250		☐ EL.-PL. SHEAR STRENGTH	6000	
☐ CURE TEMP.	300		☐ NON-LINEAR EL. MODULUS	50000	
☐ PEEL MODULUS	500000		☐ PEEL STRENGTH	10000	

---> INPUT ADHEREND PROPERTIES:

INNER			OUTER		
☐ THICKNESS (IN.)	.2		☐ THICKNESS (IN.)	.15	.25
☐ YOUNG'S MODULUS	.105e+8		☐ YOUNG'S MODULUS	0	
☐ POISSON'S RATIO	.3		☐ POISSON'S RATIO	0	
☐ THERMAL COEFF.	.000013		☐ THERMAL COEFF.	.000006	
☐ YIELD STRENGTH	65000	66000	☐ YIELD STRENGTH	0	
☐ TRANSV. MODULUS	.105e+8		☐ TRANSV. MODULUS	0	
☐ TRANSV. STRENGTH	50000		☐ TRANSV. STRENGTH	0	

RETURN　　EXECUTE　　RE-DISPLAY

Figure 15(b). Bonded Double-Lap Input (All)

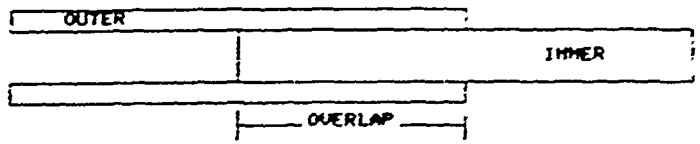
```
                    BONDED -- STANDARD DOUBLE-LAP JOINT
                       ANALYSIS NAME - BONDS-15
BASIC DATA:   LOAD TYPE       -  1 (TENSION)
              LOAD (LB/IN) -  12000.
              OVERLAP (IN) -   3.000

ADHESIVE PROPERTIES:
        MAX. SHEAR STRAIN                1.50
        BOND THICKNESS      (IN.)        .005          ELASTIC SHEAR STRENGTH (PSI)      4500.
        OPERATING TEMP.     (F.)         250.          LINEAR ELASTIC MODULUS (PSI)     70000.
        CURE TEMP.          (F.)         300.          EL.-PL. SHEAR STRENGTH (PSI)      6000.
        PEEL MODULUS        (PSI)        500000.       NON-LINEAR EL. MODULUS (PSI)     50000.
                                                       PEEL STRENGTH          (PSI)     10000.
ADHEREND PROPERTIES:                    (INNER)        (OUTER)
        THICKNESS           (IN.)       .20            .25
        YOUNG'S MODULUS     (PSI)       .105E+08       .105E+08
        POISSON'S RATIO                 .30            .30
        THERMAL COEFF.                  .0000130       .0000060
        YIELD STRENGTH      (PSI)       66000.         66000.
        TRANSV. MODULUS     (PSI)       .105E+08       .105E+08
        TRANSV. STRENGTH    (PSI)       50000.         50000.
JOINT ANALYSIS:
        OPTIMUM OVERLAP (IN.) -  2.74

        ADHESIVE SHEAR TYPE-        STRENGTH(LB/IN)    STRAIN
           ELASTIC-PLASTIC              23275.
           LINEAR ELASTIC                3651.          .064
           NON-LINEAR ELASTIC            5336.          .120
           PLASTIC                                     1.380

        ADHERENDS-  INNER               13200.
                    OUTER               33000.

        LIMIT DUE TO
        ADHESIVE PEEL OR
        INTERLAMINAR TENSION-           42905.
STRENGTH COMPUTATION
   OVERLAP (IN.) 3.00
                         BOND SHEAR STRENGTH (LB./IN.) 23269.
   BOND MORE CRITICAL WHERE INNER ADHEREND EXTENDS FROM JOINT
STRESS ANALYSIS
   APPLIED LOAD (LB./IN.) 12000.          OVERLAP (IN.) 3.00
   ELASTIC-PLASTIC SOLUTION, MAX. ADHESIVE SHEAR STRAIN  .420
                             MAX. ADHESIVE SHEAR STRESS  6000.
   ADHESIVE MORE CRITICAL WHERE INNER ADHEREND EXTENDS FROM JOINT

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *
```

Figure 15(c). Bonded Double-Lap Output

```
INPUT DATA FROM A SOLUTION ON SAVE FILE? (1=YES, 0=NO): 0

OPTIONS:  0 = RETURN TO ANALYSIS OPTIONS
          1 = INPUT ALL CONSTRAINT DATA
          2 = EDIT AVAILABLE DATA

ENTER OPTION NUMBER: 2

ENTER LOAD TYPE (1, 0, -1): -1

  2.526 CP SECONDS ELAPSED.
ENTER ANALYSIS NAME: bond15-d
```

Figure 15(d). Bonded Double-Lap Re-Analyze Page

BONDED -- STANDARD DOUBLE-LAP JOINT
ANALYSIS NAME = BOND15-D



---> INPUT JOINT CONSTRAINTS:	VALUE	MOD.
☐ LOAD TYPE (1, 0, -1)	-1	
☐ LOAD (LB./IN.)	12000.	0
☐ OVERLAP (IN.)	3.000	0

---> INPUT ADHESIVE PROPERTIES:			VALUE	MOD.
☐ MAX. SHEAR STRAIN	1.50	☐ ELASTIC SHEAR STRENGTH	4500.	
☐ BOND THICKNESS	.0050	☐ LINEAR ELASTIC MODULUS	70000.	
☐ OPERATING TEMP.	250.	☐ EL.-PL. SHEAR STRENGTH	6000.	
☐ CURE TEMP.	300.	☐ NON-LINEAR EL. MODULUS	50000.	

---> INPUT ADHEREND PROPERTIES:

INNER			OUTER		
☐ THICKNESS (IN.)	.20		☐ THICKNESS (IN.)	.25	
☐ YOUNG'S MODULUS	.105E+08		☐ YOUNG'S MODULUS	.105E+08	
☐ POISSON'S RATIO	.30		☐ POISSON'S RATIO	.30	
☐ THERMAL COEFF.	.000013		☐ THERMAL COEFF.	.000006	
☐ YIELD STRENGTH	66000.	55000	☐ YIELD STRENGTH	66000.	e

RETURN | EXECUTE | RE-DISPLAY

Figure 15(e). Bonded Double-Lap Re-Display & Modify

```
             BONDED -- STANDARD DOUBLE-LAP JOINT
                 ANALYSIS NAME - BOND15-D

BASIC DATA:  LOAD TYPE     = -1 (COMPRESSION)
             LOAD (LB/IN) =      0.
             OVERLAP (IN) =   0.000

ADHESIVE PROPERTIES:
         MAX. SHEAR STRAIN             1.50        ELASTIC SHEAR STRENGTH (PSI)    4500.
         BOND THICKNESS     (IN.)      .005        LINEAR ELASTIC MODULUS (PSI)   70000.
         OPERATING TEMP.    (F.)       250.        EL.-PL. SHEAR STRENGTH (PSI)    6000.
         CURE TEMP.         (F.)       300.        NON-LINEAR EL. MODULUS (PSI)   50000.

ADHEREND PROPERTIES:                   (INNER)        (OUTER)
         THICKNESS          (IN.)      .20            .25
         YOUNG'S MODULUS    (PSI)      .105E+08       .105E+08
         POISSON'S RATIO               .30            .30
         THERMAL COEFF.                .0000130       .0000060
         YIELD STRENGTH     (PSI)      55000.         55000.

JOINT ANALYSIS:
         OPTIMUM OVERLAP (IN.) =  2.56

         ADHESIVE SHEAR TYPE-     STRENGTH(LB/IN)   STRAIN
            ELASTIC-PLASTIC           21805.
            LINEAR ELASTIC             2181.          .064
            NON-LINEAR ELASTIC         3866.          .120
            PLASTIC                                  1.380

         ADHERENDS-  INNER            11000.
                     OUTER            27500.

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE    *  RE-ANALYZE  *  RETURN  *
```

Figure 15(f).   Bonded Double-Lap Output

BONDED UNSUPPORTED SINGLE-LAP JOINT (CODE #6)

The analysis of the unsupported single-lap joint is very similar to the description given above for the double-lap and supported single-lap. The output is unique and is covered fully.

Input Data Exceptions

Figure 16 (a) shows the input parameter for this joint. Full editing is available, and the SAVE file may be used for input. Except for the items below, the user is referred to the double-lap description above for input details.

- Load Type - Tension only
- Laminating Factor $= \dfrac{\text{actual laminate bending stiffness}}{\text{nominal homogeneous bending stiffness}}$
- Equal left and right adherend properties

Defaults

LOAD = 0: Joint strengths calculated

OVERLAP = 0: Output given for a range of 7 ℓ/t values

BOND THICKNESS = 0: .005 in. is used

LAMINATING FACTOR = 0: 1.0 (homogeneous material) is used

Output Data

Figures 16 (b) and 16 (c) show sample output for Figure 16 (a) input with the joint load specified zero and non-zero, respectively.

If LOAD = 0, the strengths of the joint are calculated to determine the following as shown in Figure 16 (b).

- Maximum tension load remote from joint.
- Maximum combined tension + bending strength at joint.
- Elastic and plastic range adhesive shear strengths.
- Limiting load based on either adhesive peel, or interlaminar tension.

If LOAD $\neq$ 0, the applied load is used to determine internal stresses as shown in Figure 16 (c).

- Average applied adherend stress far away from joint.
- Maximum induced adherend stress, at edge of overlap.
- Peak adhesive shear stress.
- Peak adhesive shear strain.
- Peak adhesive peel stress, at edge of overlap.

Asterisks (*) printed for the adhesive shear strain indicates a failure.

If OVERLAP = 0, figures 16 (d) and (e) show the results of problems 16 (a) using the 7 overlap/adherend thickness (ℓ/t) values of 10, 20, 40, 60, 80, 100 and 150.

CP Times

Approximately one second.

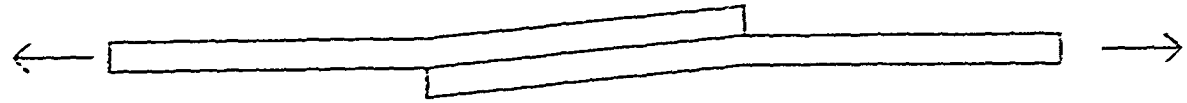
Examples

The table below relates the examples in Figure 16 to the possible input combintionns.

TABLE 1. UNSUPPORTED SINGLE-LAP OUTPUT COMBINATIONS

Figure 16	PLOAD = 0	PLOAD $\neq$ 0	OVERLAP = 0	OVERLAP $\neq$ 0
(b)	X			X
(c)		X		X
(d)	X		X	
(e)		X	X	

BONDED -- UNSUPPORTED SINGLE-LAP JOINT ANALYSIS
ANALYSIS NAME = BOND6-16



---> JOINT DATA:	VALUE	MOD.
☐ LOAD (LB./IN.)	0	
☐ OVERLAP (IN.)	2	
---> ADHESIVE PROPERTIES:		
☐ BOND THICKNESS	0	
☐ MAX. SHEAR STRAIN	1.5	
☐ ELASTIC SHEAR STR.	4500	
☐ LINEAR EL. MODULUS	70000	
☐ EL.-PL. SHEAR STR.	6000	
☐ NON-LIN. EL. MOD.	50000	
☐ PEEL STRENGTH	500000	10000
☐ PEEL MODULUS	500000	

---> ADHEREND PROPERTIES:	VALUE	MOD.
☐ THICKNESS	.3	
☐ POISSON'S RATIO	.3	
☐ TENS. YIELD STR.	65000	
☐ YOUNG'S MODULUS	.1e+8	
☐ TRANSV. STRENGTH	50000	
☐ TRANSV. MODULUS	.1e+8	
☐ LAMINATING FACTOR	0	

RETURN   EXECUTE   RE-DISPLAY

Figure 16(a). Bonded Unsupported Single-Lap Input

```
BONDED -- UNSUPPORTED SINGLE-LAP JOINT ANALYSIS
            ANALYSIS NAME - BOND6-16

JOINT DATA:                 VALUE
      LOAD (LB./IN.),          0.
      OVERLAP  (IN.),        2.00

ADHESIVE PROPERTIES:                                          ADHEREND PROPERTIES:   VALUE
      BOND THICKNESS        .0050                                   THICKNESS           .30
      MAX. SHEAR STRAIN     1.500                                   POISSON'S RATIO     .30
      ELASTIC SHEAR STR.    4500.                                   TENS. YIELD STR.    65000.
      LINEAR EL. MODULUS   70000.                                   YOUNG'S MODULUS     .100E+08
      EL.-PL. SHEAR STR.    6000.                                   TRANSU. STRENGTH   50000.
      NON-LIN. EL. MOD.    50000.                                   TRANSU. MODULUS     .100E+08
      PEEL STRENGTH        10000.                                   LAMINATING FACTOR  1.0000
      PEEL MODULUS        500000.

JOINT STRENGTHS (LB./IN.):
     ADHEREND:  REMOTE TENSION     19500.
                TENSION + BENDING   6685.

     BOND SHEAR:  ELASTIC           1602.
                  PLASTIC          12000.

     LIMIT DUE TO ADHESIVE PEEL
         OR INTERLAMINAR TENSION-   2182.

*  OUTPUT TO PRINT FILE *  OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *
                               (COMPLETE)
```

Figure 16(b). Bonded Unsupported Single-Lap Output (P=0, OL≠0)

```
BONDED -- UNSUPPORTED SINGLE-LAP JOINT ANALYSIS
            ANALYSIS NAME - BOND6-17

JOINT DATA:                   VALUE                        ADHEREND PROPERTIES:   VALUE

      LOAD (LB./IN.),          3000.                             THICKNESS           .30

      OVERLAP  (IN.),          2.00                              POISSON'S RATIO     .30

ADHESIVE PROPERTIES:                                             TENS. YIELD STR.    65000.

      BOND THICKNESS          .0050                              YOUNG'S MODULUS     .100E+02

      MAX. SHEAR STRAIN       1.500                              TRANSU. STRENGTH    50000.

      ELASTIC SHEAR STR.       4500.                             TRANSU. MODULUS     .100E+08

      LINEAR EL. MODULUS      70000.                             LAMINATING FACTOR   1.0000

      EL.-PL. SHEAR STR.       6000.

      NON-LIN. EL. MOD.       50000.

      PEEL STRENGTH           10000.

      PEEL MODULUS           500000

INTERNAL STRESSES (PSI):

    ADHEREND: AVE. APPLIED STRESS  10000.
              MAX. INDUCED STRESS  31921.

    ADHESIVE:   PEAK SHEAR STRESS   6000.
                PEAK SHEAR STRAIN    .124
                PEAK PEEL  STRESS  12969.

* OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   * RE-ANALYZE * RETURN *
```

Figure 16(c). Bonded Unsupported Single-Lap Output (P≠0, OL≠0)

```
BONDED -- UNSUPPORTED SINGLE-LAP JOINT ANALYSIS
         ANALYSIS NAME = BOND16-D
```

JOINT DATA:

	VALUE
LOAD (LB./IN.),	0.
OVERLAP (IN.),	0.00

ADHESIVE PROPERTIES:

	VALUE
BOND THICKNESS	.0050
MAX. SHEAR STRAIN	1.500
ELASTIC SHEAR STR.	4500.
LINEAR EL. MODULUS	70000.
EL.-PL. SHEAR STR.	6000.
NON-LIN. EL. MOD.	50000.
PEEL STRENGTH	10000.
PEEL MODULUS	500000.

ADHEREND PROPERTIES:	VALUE
THICKNESS	.30
POISSON'S RATIO	.30
TENS. YIELD STR.	65000.
YOUNG'S MODULUS	.100E+08
TRANSV. STRENGTH	50000.
TRANSV. MODULUS	.100E+08
LAMINATING FACTOR	1.0000

JOINT STRENGTHS (LB./IN.):

		L/T RATIO 10	20	40	60	80	100	150
ADHEREND:	REMOTE TENSION	19500.	19500.	19500.	19500.	19500.	19500.	19500.
	TENSION + BENDING	7689.	10658.	14703.	16642.	17626.	18183.	18833.
BOND SHEAR:	ELASTIC	1730.	2149.	2985.	3647.	4110.	4428.	4872.
	PLASTIC	13169.	14887.	19572.	36256.	38644.	40108.	42044.
LIMIT DUE TO ADHESIVE PEEL OR INTERLAMINAR TENSION-		2474.	3720.	15542.	29530.	47737.	70049.	143517.

* OUTPUT TO PRINT FILE * OUTPUT TO SAVE FILE * RE-ANALYZE * RETURN *

Figure 16(d). Bonded Unsupported Single-Lap Output (P=0, OL=0)

```
BONDED -- UNSUPPORTED SINGLE-LAP JOINT ANALYSIS
                 ANALYSIS NAME = BOND16-E

JOINT DATA:                      VALUE
     LOAD (LB./IN.),             10000.
     OVERLAP  (IN.),              0.00

ADHESIVE PROPERTIES:                                        ADHEREND PROPERTIES:   VALUE
     BOND THICKNESS             .0050                           THICKNESS            .30
     MAX. SHEAR STRAIN          1.500                           POISSON'S RATIO      .30
     ELASTIC SHEAR STR.         4500.                           TENS. YIELD STR.     65000.
     LINEAR EL. MODULUS         70000.                          YOUNG'S MODULUS      .100E+08
     EL.-PL. SHEAR STR.         6000.                           TRANSV. STRENGTH     50000.
     NON-LIN. EL. MOD.          50000.                          TRANSV. MODULUS      .100E+08
     PEEL STRENGTH              10000.                          LAMINATING FACTOR    1.0000
     PEEL MODULUS              500000.

INTERNAL STRESSES (PSI):
                                                        L/T RATIO
                                   10       20       40       60       80      100      150
   ADHEREND: AVE. APPLIED STRESS  33333.   33333.   33333.   33333.   33333.   33333.   33333.
             MAX. INDUCED STRESS  80826.   61787.   47141.   41541.   38786.   37223.   35356.
   ADHESIVE:   PEAK SHEAR STRESS   6000.    6000.    6000.    6000.    6000.    6000.    6000.
               PEAK SHEAR STRAIN   .554     .329     .210     .175     .159     .151     .141
               PEAK PEEL   STRESS 28097.   16833.    8169.    4856.    3226.    2301.    1197.

* OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE   * RE-ANALYZE * RETURN *
```

Figure 16(e). Bonded Unsupported Single-Lap Output ($P \neq 0$, $OL=0$)

BONDED STEPPED-LAP ANALYSIS (CODE #8)

The user has the option of analyzing either a joint or doubler, and may choose a single bond surface. A two-bond typical stepped-lap picture is displayed. The analysis routine will subdivide the length of each step as necessary to solve the problem.

Input Data

Figure 17 (a) is a picture of the screen after entering the data to a four-step joint. The user is prompted for all data values by groups. If editing must be done to any item in a group, the RE-INPUT option will allow re-entering that group of items after all initial data is complete.

Basic Data Group

- LOAD TYPE: 1 = Tension
  0 = In-plane shear
  -1 = Compression
- No. of steps to be entered.
- Temp. Differential = Operating Temp. - Cure Temp.
- Sym. stress distribution (for joints only), assumes equal inner and outer stresses at opposing ends of the joint. This prevents reversing of inner and outer ends for a symmetric model.
- Single bond surface. Figure 18 shows some typical single-bonded joints and doublers.

Adhesive Properties

- Bond thickness (constant along joint)
- Peak shear stress
- Elastic shear modulus
- Maximum shear strain (elastic + plastic)

Adherend Properties

- Outer and inner coeff. of thermal expansion
- Step-length
- Effective thickness
- Extensional stiffness modulus
- Strength

for each step

Defaults

Bond thickness = 0: .005 inch is used

Re-Input Option

When the user has all of the input data specified, he may modify any item before executing the analysis routine. The RE-INPUT option will clear the screen, and go through the process shown in Figure 17 (b). When modifying data, all items of a group must be input, including those that remain unchanged. If step data is to be modified, the step number is requested before being prompted to re-input the step properties. Entering a zero step number stops the step editing and allows the user to select a new option. If the number of steps is modified in the basic input data, the data for all steps is requested automatically.

Output Data Description

The bonded stepped-lap analysis is unique in that its output may contain more data than can be displayed on the screen in one page. Displaying the data one page at a time would normally be acceptable only to those users with a hardcopy thermal printer. Therefore, the results will only be summarized after an analysis. The user may optionally output the full solution to the PRINT file either after the analysis or later in the selective output processing mode if saved.

Complete Print File Output

Figures 17 (c) thru (f) show the complete output for the problem defined in figures 17 (a) and (b). Since this is generally more than can be displayed on one page for the screen, a summary of pertinent data, Figure 17 (g), is provided the user after an execution.

Figure 17 (c) is simply the input data provided by the user to define the problem.

Figures 17 (d) - (f) are the output analyses. The stepped-lap analysis routine artifically subdivides the input steps if required to prevent numerical instabilities. These substeps are a function of the adhesive transition from elastic to plastic behavior.

For a joint, an analysis is valid only if the outer load for the first step is equal to the inner load for the last step.

For a doubler, a solution is valid only if the outer load for the first step is equal to the sum of the inner plus outer loads for the last step, and the last gamma value equals zero.

If a solution is indicated as being divergent, the output data for that solution is to be ignored. Because thermal stresses may exceed the elastic adhesive capability without any mechanical load when metals are bonded to composites, it is not uncommon for a divergent elastic solution to be followed by a satisfactory elastic-plastic solution.

The maximum joint load for each analysis is indicated by the load in the outer adherend for the first step. A comparison of the first and last values of TAU (elastic analysis) and GAMMA (elastic-plastic analyses) indicate to what extent each end of the joint is contributing to the load transfer, with equal strain the most desirable. Grossly dissimilar strains indicate that balancing the adherend stiffness, ET, at each end of the joint may improve the design.

For the elastic-plastic analysis, the user may make an outer adherend strength assessment by comparing the load with the strength on the same line; for the inner adherend, the load is compared with the strength one line higher. The two critical areas for the outer adherend are most likely to be the start of the first and last geometric steps; the two for the inner adherend are most likely to be the end of the first and last geometric steps. Figure 17 (e) shows these comparisons, of which the critical inner and outer values computed and printed in the display summary only.

If the weak link in the joint is in either of the adherends, the adherend strengths are set sufficiently high, "Infinite Adherend Strength", to calculate the applied load necessary to fail the adhesive. This strength is also indicated by the outer load in the first step.

Summary Display

Figure 17 (g) is a summary display page for the full output of Figure 17 (d) - (f).

The "allowables" are adhesive shear values input for Tau max. and Gamma max.

The joint strengths are those values given for the outer load of the first step.

The critical inner and outer adherend strengths are obtained from the minimum ratio of load/strength. The connecting lines shown in Figure 17 (e) show which values are used for those ratios.

The full output may be displayed by selecting the SAVE option and using main option #2 (reference Section VI).

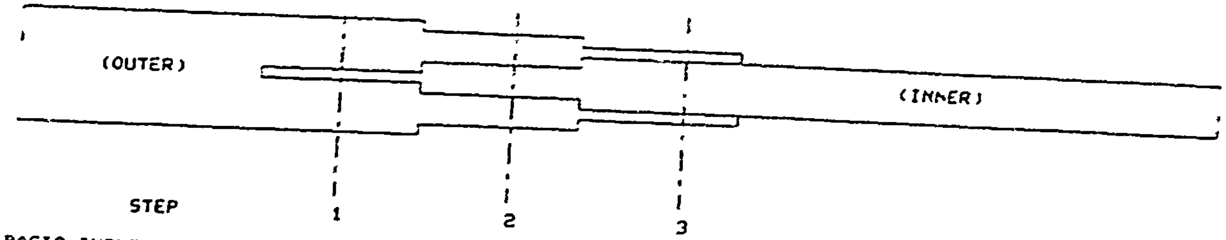
CP Times

Varies from 1 to 60 seconds depending on the number of steps.

Examples

Figure 17 details the maximum output summary for the stepped-lap joint. Depending on the allowables used, solutions may not be calculated for the elastic-plastic or the infinite adherend allowable cases.

BONDED STEPPED-LAP JOINT ANALYSIS
ANALYSIS NAME = BOND8-2




```
BASIC INPUT DATA:

     1) LOAD TYPE (1=TENS, 0=SHEAR, -1=COMPR.)
     2) NO. OF STEPS
     3) TEMP. DIFFERENTIAL
     4) ASSUME SYM. STRESS DISTR.? (0=NO, 1=YES)
     5) SINGLE BOND SURFACE?       (0=NO, 1=YES)

ADHESIVE PROPERTIES:

     1) BOND THICKNESS        (ETA)
     2) PEAK SHEAR STRESS     (TAU MAX.)
     3) ELASTIC SHEAR MODULUS (G)
     4) MAXIMUM SHEAR STRAIN  (GAMMA MAX.)

ADHEREND PROPERTIES:

     1) THERMAL EXPANSION COEFFICIENTS
     2) STEP DATA: L   = LENGTH
                   T   = EFF. THICKNESS
                   ET  = EXT. STIFFNESS
                   STR = STRENGTH

ENTER 5 BASIC DATA VALUES: -1 4 10 0 0
ENTER 4 ADHESIVE VALUES: .01 5000 55000 1.5
ENTER OUTER & INNER COEFF. : .000013 .000006
ENTER L, T(O), T(I), ET(O), ET(I), STR(O), STR(I), FOR EACH STEP.
STEP  1 :  2 .7 .2 1050000 1100000 7000 6500
STEP  2 :  2.5 .5 .3 1000000 950000 7500 6000
STEP  3 :  2.5 .3 .4 1100000 1140000 7000 6800
STEP  4 :  3 .1 .5 1230000 1100000 6000 7000
```

RETURN | EXECUTE | RE-INPUT

Figure 17(a). Bonded Stepped-Lap Joint Input

```
NEW EXISTING INPUT DATA? (0=NO, 1=YES): 1
        BONDED STEPPED-LAP JOINT ANALYSIS


        BASIC INPUT DATA:

             LOAD TYPE     = COMPRESSION
             NO. OF STEPS =  4
             TEMP. DIFF.  =   10.
             2-BOND SURFACE


        ADHESIVE PROPERTIES:

             BOND THICKNESS          (ETA)          .0100
             PEAK SHEAR STRESS       (TAU MAX.)     5000.
             ELASTIC SHEAR MODULUS   (G)              55000.
             MAXIMUM SHEAR STRAIN    (GAMMA MAX.)   1.500
             ELASTIC SHEAR STRAIN    (GAMMA EL.)    0.000


        ADHEREND PROPERTIES:

             OUTER THERMAL EXPANSION COEFF. = .0000130
             INNER THERMAL EXPANSION COEFF. = .0000060

                          ** THICKNESS **      EXTENSIONAL STIFFNESS       *** STRENGTH ***
  STEP      LENGTH      OUTER       INNER       OUTER          INNER        OUTER       INNER

   1        2.0000      .7000       .2000     1050000.       1100000.       7000.       6500.
   2        2.5000      .5000       .3000     1000000.        980000.       7500.       6000.
   3        2.5000      .3000       .4000     1100000.       1140000.       7000.       6800.
   4        3.0000      .1000       .5000     1200000.       1100000.       6000.       7000.
UPDATE BASIC DATA? (0=NO, 1=YES): 1

ENTER 5 BASIC DATA VALUES: -1 4 -50 0 0

UPDATE ADHESIVE VALUES? (0=NO, 1=YES): 0

UPDATE THERMAL COEFF.? (0=NO, 1=YES): 0

UPDATE STEP DATA? (0=NO, 1=YES): 1

ENTER STEP NO. (0 = END): 2

ENTER L, T(O), T(I), ET(O), ET(I), STR(O), STR(I), FOR STEP  2
2.5 .5 .3 1000000 950000 7500 6000

ENTER STEP NO. (0 = E  ): 0
```

RETURN | EXECUTE | RE-INPUT

Figure 17(b). Bonded Stepped-Lap Joint Re-Input (Editing)

```
              ADHESIVE-BONDED STEPPED-LAP JOINT ANALYSIS
                     ANALYSIS NAME = BONDB-2


       BASIC INPUT DATA:

            LOAD TYPE      = COMPRESSION
            NO. OF STEPS =   4
            TEMP. DIFF.  =   -50.
            2-BOND SURFACE


       ADHESIVE PROPERTIES:

            BOND THICKNESS          (ETA)           .0100
            PEAK SHEAR STRESS       (TAU MAX.)      5000.
            ELASTIC SHEAR MODULUS   (G)              55000.
            MAXIMUM SHEAR STRAIN    (GAMMA MAX.)    1.500
            ELASTIC SHEAR STRAIN    (GAMMA EL.)      .091


       ADHEREND PROPERTIES:

            OUTER THERMAL EXPANSION COEFF. = .0000130
            INNER THERMAL EXPANSION COEFF. = .0000060
```

STEP	LENGTH	** THICKNESS ** OUTER	** THICKNESS ** INNER	EXTENSIONAL STIFFNESS OUTER	EXTENSIONAL STIFFNESS INNER	*** STRENGTH *** OUTER	*** STRENGTH *** INNER
1	2.0000	.7000	.2000	10500000.	11000000.	7000.	6500.
2	2.5000	.5000	.3000	10000000.	9500000.	7500.	6000.
3	2.5030	.3000	.4000	11000000.	11400000.	7000.	6800.
4	3.0000	.1000	.4000	12000000.	11000000.	6000.	7000.

Figure 17(c). Bonded Stepped-Lap Joint Output - Input Data

ELASTIC ANALYSIS

STEP	LENGTH	THICKO	THICKI	TAU	GAMMA	DELTAO	DELTAI	*** OUTER *** LOAD	STRENGTH	*** INNER *** LOAD	STRENGTH
1	.5000	.7000	.2000	5000.	.091	0.0000	-.0009	3952.	7000.	0.	6500.
2	.5000	.7000	.2000	550.	.009	-.0016	-.0017	1972.	7000.	1980.	6500.
3	.5000	.7000	.2000	53.	.001	-.0028	-.0028	1767.	7000.	2185.	6500.
4	.5000	.7000	.2000	-8.	-.000	-.0039	-.0039	1751.	7000.	2201.	6500.
5	.6250	.5000	.3000	-132.	-.002	-.0051	-.0051	1801.	7500.	2151.	6000.
6	.6250	.5000	.3000	-7.	-.000	-.0067	-.0066	1853.	7500.	2099.	6000.
7	.6250	.5000	.3000	-0.	-.000	-.0082	-.0082	1856.	7500.	2096.	6000.
8	.6250	.5000	.3000	7.	.000	-.0098	-.0098	1853.	7500.	2099.	6000.
9	.6250	.3000	.4000	128.	.002	-.0113	-.0114	1802.	7000.	2150.	6800.
10	.6250	.3000	.4000	8.	.000	-.0127	-.0127	1748.	7000.	2204.	6800.
11	.6250	.3000	.4000	-0.	-.000	-.0141	-.0141	1745.	7000.	2207.	6800.
12	.6250	.3000	.4000	-8.	-.000	-.0155	-.0155	1748.	7000.	2204.	6800.
13	.7500	.1000	.5000	-128.	-.002	-.0170	-.0169	1802.	6000.	2149.	7000.
14	.7500	.1000	.5000	-5.	-.000	-.0186	-.0186	1859.	6000.	2093.	7000.
15	.7500	.1000	.5000	6.	.000	-.0202	-.0202	1858.	6000.	2094.	7000.
16	.7500	.1000	.5000	153.	.003	-.0219	-.0219	1791.	6000.	2161.	7000.
17	0.0000	0.0000	.5000	4074.	.074	-.0232	-.0239	-0.	0.	3952.	7000.

NOTE: Circled numbers included in summary.

Figure 17(d). Bonded Stepped-Lap Joint - Elastic Analysis

ELASTIC-PLASTIC ANALYSIS

STEP	LENGTH	THICKO	THICKI	TAU	GAMMA	DELTAO	DELTAI	*** OUTER *** LOAD	STRENGTH	*** INNER *** LOAD	STRENGTH
1	.1559	.7000	.2000	5000.	-.178	0.0000	-.0018	7000.	7000.	0.	6500.
2	.3441	.7000	.2000	5000.	.091	-.0010	-.0019	5440.	7000.	1559.	6500.
3	0.0000	.7000	.2000	1054.	.019	-.0027	-.0029	3696.	7000.	3303.	6500.
4	.5000	.7000	.2000	1054.	.019	-.0027	-.0029	3696.	7000.	3303.	6500.
5	0.0000	.7000	.2000	107.	.002	-.0046	-.0046	3280.	7000.	3720.	6500.
6	0.0000	.7000	.2000	107.	.002	-.0046	-.0046	3280.	7000.	3720.	6500.
7	.5000	.7000	.2000	107.	.002	-.0046	-.0046	3280.	7000.	3720.	6500.
8	0.0000	.7000	.2000	-11.	-.000	-.0065	-.0065	3246.	7000.	3754.	6500.
9	0.0000	.7000	.2000	-11.	-.000	-.0065	-.0065	3246.	7000.	3754.	6500.
10	.5000	.7000	.2000	-11.	-.000	-.0065	-.0065	3246.	7000.	3754.	6500.
11	0.0000	.7000	.2000	-217.	-.004	-.0084	-.0083	3328.	7000.	3672.	6500.
12	0.0000	.7000	.2000	-217.	-.004	-.0084	-.0083	3328.	7000.	3672.	6500.
13	.6250	.5000	.3000	-217.	-.004	-.0084	-.0083	3328.	7500.	3672.	6000.
14	0.0000	.5000	.3000	-11.	-.000	-.0109	-.0109	3414.	7500.	3585.	6000.
15	0.0000	.5000	.3000	-11.	-.000	-.0109	-.0109	3414.	7500.	3585.	6000.
16	.6250	.5000	.3000	-11.	-.000	-.0109	-.0109	3414.	7500.	3585.	6000.
17	0.0000	.5000	.3000	-0.	-.000	-.0134	-.0134	3419.	7500.	3581.	6000.
18	0.0000	.5000	.3000	-0.	-.000	-.0134	-.0134	3419.	7500.	3581.	6000.
19	.6250	.5000	.3000	-0.	-.000	-.0134	-.0134	3419.	7500.	3581.	6000.
20	0.0000	.5000	.3000	10.	.000	-.0160	-.0160	3415.	7500.	3585.	6000.
21	0.0000	.5000	.3000	10.	.000	-.0160	-.0160	3415.	7500.	3585.	6000.
22	.6250	.5000	.3000	10.	.000	-.0160	-.0160	3415.	7500.	3585.	6000.
23	0.0000	.5000	.3000	204.	.004	-.0185	-.0186	3333.	7500.	3666.	6000.
24	0.0000	.5000	.3000	204.	.004	-.0185	-.0186	3333.	7500.	3666.	6000.
25	.6250	.3000	.4000	204.	.004	-.0185	-.0186	3333.	7000.	3666.	6800.
26	0.0000	.3000	.4000	13.	.000	-.0208	-.0208	3247.	7000.	3753.	6800.
27	0.0000	.3000	.4000	13.	.000	-.0208	-.0208	3247.	7000.	3753.	6800.
28	.6250	.3000	.4000	13.	.000	-.0208	-.0208	3247.	7000.	3753.	6800.
29	0.0000	.3000	.4000	-0.	-.000	-.0230	-.0230	3242.	7000.	3758.	6800.
30	0.0000	.3000	.4000	-0.	-.000	-.0230	-.0230	3242.	7000.	3758.	6800.
31	.6250	.3000	.4000	-0.	-.000	-.0230	-.0230	3242.	7000.	3758.	6800.
32	0.0000	.3000	.4000	-14.	-.000	-.0253	-.0253	3248.	7000.	3752.	6800.
33	0.0000	.3000	.4000	-14.	-.000	-.0253	-.0253	3248.	7000.	3752.	6800.
34	.6250	.3000	.4000	-14.	-.000	-.0253	-.0253	3248.	7000.	3752.	6800.
35	0.0000	.3000	.4000	-231.	-.004	-.0276	-.0275	3346.	7000.	3654.	6800.
36	0.0000	.3000	.4000	-231.	-.004	-.0276	-.0275	3346.	7000.	3654.	6800.
37	.7500	.1000	.5000	-231.	-.004	-.0276	-.0275	3346.	6000.	3654.	7000.
38	0.0000	.1000	.5000	-8.	-.000	-.0302	-.0302	3447.	6000.	3553.	7000.
39	0.0000	.1000	.5000	-8.	-.000	-.0302	-.0302	3447.	6000.	3553.	7000.
40	.7500	.1000	.5000	-8.	-.000	-.0302	-.0302	3447.	6000.	3553.	7000.
41	0.0000	.1000	.5000	11.	.000	-.0328	-.0328	3446.	6000.	3554.	7000.
42	0.0000	.1000	.5000	11.	.000	-.0328	-.0328	3446.	6000.	3554.	7000.
43	.7500	.1000	.5000	11.	.000	-.0328	-.0328	3446.	6000.	3554.	7000.
44	0.0000	.1000	.5000	312.	.006	-.0354	-.0355	3308.	6000.	3691.	7000.
45	0.0000	.1000	.5000	312.	.006	-.0354	-.0355	3308.	6000.	3691.	7000.
46	.6333	.1000	.5000	312.	.006	-.0354	-.0355	3308.	6000.	3691.	7000.
47	.1167	.1000	.5000	5000.	.091	-.0373	-.0382	1167.	6000.	5833.	7000.
48	0.0000	.1000	.5000	5000.	.149	-.0374	-.0389	-0.	6000.	7000.	7000.
49	0.0000	0.0000	.5000	5000.	.149	-.0374	-.0389	-0.	0.	7000.	7000.

NOTE: Circled numbers included in summary.

Figure 17(e). Bonded Stepped-Lap Joint - Elastic-Plastic Analysis

ELASTIC-PLASTIC ANALYSIS
(INFINITE ADHEREND STRENGTH)

STEP	LENGTH	THICKO	THICKI	TAU	GAMMA	DELTAO	DELTAI	OUTER LOAD	INNER LOAD
1	.5000	.7000	.2000	5000.	1.500	0.0000	-.0150	24069.	0.
2	0.0000	.7000	.2000	5000.	.569	-.0106	-.0163	19069.	5000.
3	0.0000	.7000	.2000	5000.	.569	-.0106	-.0163	19069.	5000.
4	.5000	.7000	.2000	5000.	.569	-.0106	-.0163	19069.	5000.
5	0.0000	.7000	.2000	5000.	.103	-.0188	-.0198	14069.	10000.
6	0.0000	.7000	.2000	5000.	.103	-.0188	-.0198	14069.	10000.
7	.0285	.7000	.2000	5000.	.103	-.0188	-.0198	14069.	10000.
8	.4715	.7000	.2000	5000.	.091	-.0192	-.0201	13784.	10285.
9	0.0000	.7000	.2000	520.	.009	-.0251	-.0252	11861.	12208.
10	.5000	.7000	.2000	520.	.009	-.0251	-.0252	11861.	12208.
11	0.0000	.7000	.2000	-639.	-.012	-.0311	-.0309	11904.	12166.
12	0.0000	.7000	.2000	-639.	-.012	-.0311	-.0309	11904.	12166.
13	.6250	.5000	.3000	-639.	-.012	-.0311	-.0309	11904.	12166.
14	0.0000	.5000	.3000	-33.	-.001	-.0390	-.0390	12159.	11910.
15	0.0000	.5000	.3000	-33.	-.001	-.0390	-.0390	12159.	11910.
16	.6250	.5000	.3000	-33.	-.001	-.0390	-.0390	12159.	11910.
17	0.0000	.5000	.3000	-0.	-.000	-.0470	-.0470	12171.	11898.
18	0.0000	.5000	.3000	-0.	-.000	-.0470	-.0470	12171.	11898.
19	.6250	.5000	.3000	-0.	-.000	-.0470	-.0470	12171.	11898.
20	0.0000	.5000	.3000	32.	.001	-.0550	-.0551	12159.	11910.
21	0.0000	.5000	.3000	32.	.001	-.0550	-.0551	12159.	11910.
22	.6250	.5000	.3000	32.	.001	-.0550	-.0551	12159.	11910.
23	0.0000	.5000	.3000	629.	.011	-.0630	-.0631	11908.	12161.
24	0.0000	.5000	.3000	629.	.011	-.0630	-.0631	11908.	12161.
25	.6250	.3000	.4000	629.	.011	-.0630	-.0631	11908.	12161.
26	0.0000	.3000	.4000	39.	.001	-.0701	-.0701	11642.	12428.
27	0.0000	.3000	.4000	39.	.001	-.0701	-.0701	11642.	12428.
28	.6250	.3000	.4000	39.	.001	-.0701	-.0701	11642.	12428.
29	0.0000	.3000	.4000	-1.	-.000	-.0771	-.0771	11626.	12443.
30	0.0000	.3000	.4000	-1.	-.000	-.0771	-.0771	11626.	12443.
31	.6250	.3000	.4000	-1.	-.000	-.0771	-.0771	11626.	12443.
32	0.0000	.3000	.4000	-80.	-.001	-.0841	-.0841	11647.	12423.
33	0.0000	.3000	.4000	-80.	-.001	-.0841	-.0841	11647.	12423.
34	.6250	.3000	.4000	-80.	-.001	-.0841	-.0841	11647.	12423.
35	0.0000	.3000	.4000	-807.	-.015	-.0912	-.0910	11988.	12081.
36	0.0000	.3000	.4000	-807.	-.015	-.0912	-.0910	11988.	12081.
37	.7500	.1000	.5000	-807.	-.015	-.0912	-.0910	11988.	12081.
38	0.0000	.1000	.5000	-9.	-.000	-.0993	-.0993	12333.	11736.
39	0.0000	.1000	.5000	-9.	-.000	-.0993	-.0993	12333.	11736.
40	.7500	.1000	.5000	-9.	-.000	-.0993	-.0993	12333.	11736.
41	0.0000	.1000	.5000	577.	.010	-.1075	-.1076	12092.	11977.
42	0.0000	.1000	.5000	577.	.010	-.1075	-.1076	12092.	11977.
43	.4927	.1000	.5000	577.	.010	-.1075	-.1076	12092.	11977.
44	.2573	.1000	.5000	5000.	.091	-.1125	-.1134	10073.	13997.
45	0.0000	.1000	.5000	5000.	.251	-.1145	-.1171	7500.	16569.
46	.7500	.1000	.5000	5000.	.251	-.1145	-.1171	7500.	16569.
47	0.0000	.1000	.5000	5000.	1.376	-.1174	-.1311	-0.	24069.
48	0.0000	.1000	.5000	5000.	1.376	-.1174	-.1311	-0.	24069.
49	0.0000	0.0000	.5000	5000.	1.376	-.1174	-.1311	-0.	24069.

NOTE: Circled numbers included in summary.

Figure 17(f). Bonded Stepped-Lap Joint Output - El. - Pl. Analysis With Infinite Adherend Strength

```
                 BONDED STEPPED-LAP JOINT ANALYSIS SUMMARY
                       ANALYSIS NAME - BOND8-2

                           ELASTIC SOLUTION

    JOINT STRENGTH (LBS) -      3952.

    ADHESIVE SHEAR STRESS (PSI):  ALLOUABLE  -   5000.
                                  FIRST STEP -   5000.
                                  LAST  STEP -   4074.

                        ELASTIC-PLASTIC SOLUTION

    JOINT STRENGTH (LBS) -      7000.

    ADHESIVE SHEAR STRAIN:   ALLOUABLE  -  1.500
                             FIRST STEP -   .178
                             LAST  STEP -   .149

    CRITICAL STRENGTH (PSI):  ACTUAL  ALLOUABLE
                     OUTER:   7000.    7000.
                     INNER:   7000.    7000.


             *** INFINITE ADHEREND ALLOUABLE SOLUTION ***

    JOINT STRENGTH (LBS) -    24069.

    ADHESIVE SHEAR STRAIN:   ALLOUABLE  -  1.500
                             FIRST STEP -  1.500
                             LAST  STEP -  1.376

* OUTPUT TO PRINT FILE *  OUTPUT TO SAVE FILE   * RE-ANALYZE * RETURN *

                      (COMPLETE)




    (COMPLETE)
```

Figure 17(g). Bonded Stepped-Lap Joint Output Summary

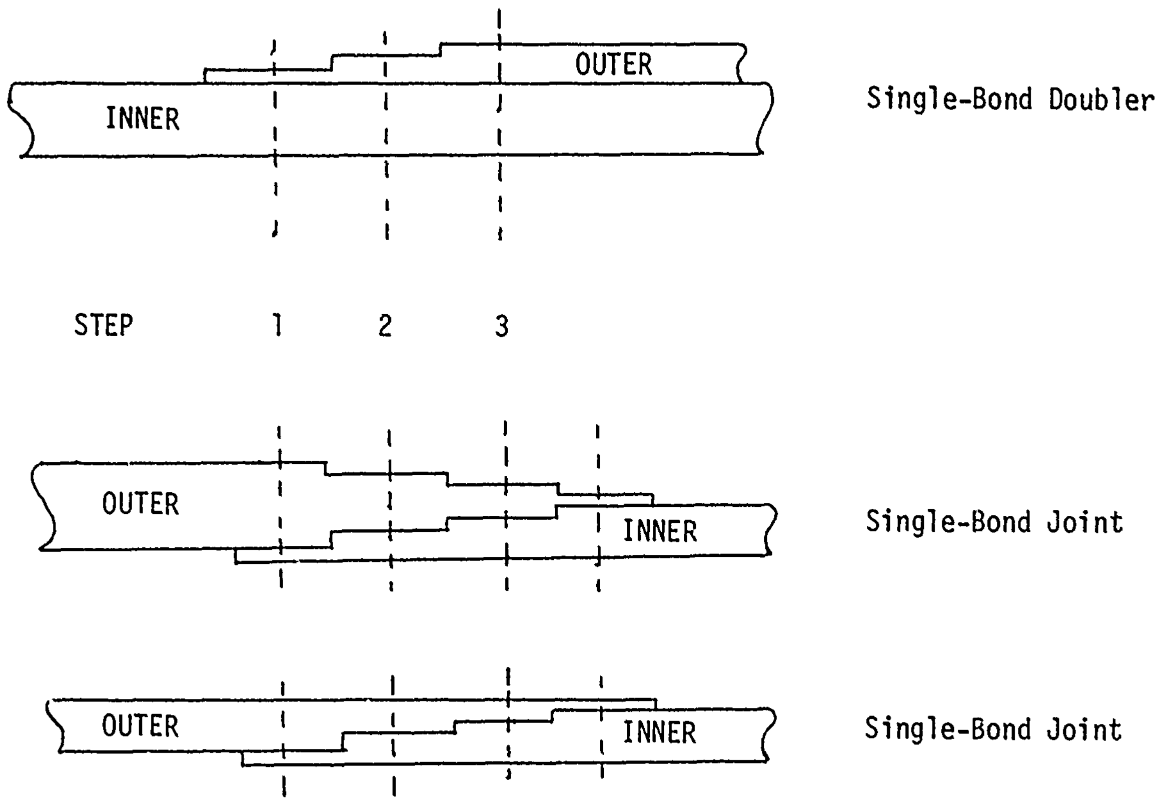


Figure 18. Typical Single-Bond Stepped-Lap Joints and Doublers

BONDED SCARF JOINT (CODE #9)

The bonded scarf joint may be analyzed for a tension, compression, or in-plane shear load. Bond shear stresses only are considered, so peel stresses are neglected in accordance with the very small scarf angles used in practice.

The user is requested to designate either 1 or 2 bonding surfaces for the problem, representing either asymmetrical or symmetrical joint geometry.

The SAVE file may be used for input, and individual item editing is utilized.

Input Data

Figure 19 (a) shows an example of the input data required. It is identical to the form used for the bonded double-lap joint and bonded supported single-lap joint, without need for the peel and transverse items.

To reduce computational time, the user should attempt to place the more critical adherend on the left "inner" side. If the ends were reversed to satisfy this computational requirement, a message will be displayed above the output display informing the user of the switch.

Defaults

If these items are set = 0, the following default values will be used.

LOAD - adherend and adhesive strengths determined.

OVERLAP - output will be displayed for a range of 7 overlap lengths.

BOND THICKNESS = .005 inch.

Except for the THERMAL COEFF. any zero OUTER adherend value will allow the corresponding INNER values to be copied.

Editing

After input is complete, the user may modify values. Refer to the editing subsection of the bonded double-lap joint for details.

Output Description

Figure 19 (b) shows the output for the Figure 19 (a) problem, with the LOAD value specified. Figure 19 (c) is the output for the same problem, except the LOAD = 0 to determine strengths.

When OVERLAP = 0 is input, the program uses a range of overlaps based on the left end adherend thickness and ℓ/t values of 10, 20, 40, 60, 80, 100, and 150.

The critical end of the joint is identified as either L (left end) or R (right end). If both ends are equally critical, the end is left blank. Since the JOINT program attempts to make the left end critical, that end (L) will normally be identified.

Load $\neq$ 0

Figure 19 (b) contains the internal stresses (psi) computed for the applied load level.

Adherend stresses are determined far away from the joint effects, and failure is determined by comparison with the yield strength.

Peak shear stress and strain are computed for the associated overlap(s), with asterisks(*) indicating failure.

Load = 0

Figure 19 (c) contains the typical strengths in lb/in. computed for the joint.

Adherend strengths of the left and right ends are computed far away from the effects of the joint.

Adhesive shear strengths for the overlap(s) are calculated for the three strain regions shown, along with the corresponding critical end.

The overlaps, if not specified, are based on the /t ratios.

From the calculated strengths, the user may identify the limiting load levels and associated overlaps.

CP Times

Approximately one second.

Examples

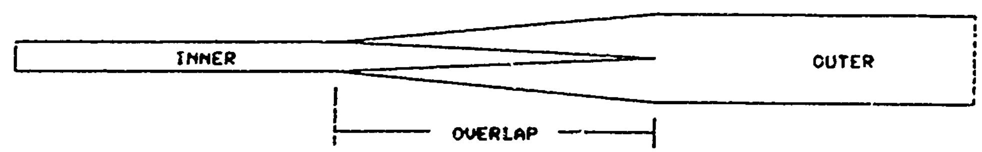
Figure 19 (a) Typical input using all defaults except LOAD

(b) Output for Figure 19 (a)

(c) Output: LOAD = 0, OVERLAP = 0

(d) Output: LOAD = 0, OVERLAP = 2.0, ends reversed

BONDED -- SYMMETRICAL SCARF JOINT
ANALYSIS NAME = BOND-19A



---> INPUT JOINT CONSTRAINTS:	VALUE	MOD.
☐ LOAD TYPE (1, 0, -1)	1	
☐ LOAD (LB./IN.)	10000.	
☐ OVERLAP (IN.)	2.500	2.0

---> INPUT ADHESIVE PROPERTIES:

	VALUE			VALUE	MOD.
☐ MAX. SHEAR STRAIN	1.10		☐ ELASTIC SHEAR STRENGTH	4000.	
☐ BOND THICKNESS	.0050		☐ LINEAR ELASTIC MODULUS	70000.	
☐ OPERATING TEMP.	70.		☐ EL.-PL. SHEAR STRENGTH	5000.	
☐ CURE TEMP.	120.		☐ NON-LINEAR EL. MODULUS	50000.	

---> INPUT ADHEREND PROPERTIES:

INNER		OUTER	
☐ THICKNESS (IN.)	.10	☐ THICKNESS (IN.)	.20
☐ YOUNG'S MODULUS	.150E+08	☐ YOUNG'S MODULUS	.100E+08
☐ POISSON'S RATIO	.40	☐ POISSON'S RATIO	.30
☐ THERMAL COEFF.	.000000	☐ THERMAL COEFF.	.000013
☐ YIELD STRENGTH	150000.	☐ YIELD STRENGTH	70000.

RETURN   EXECUTE   RE-DISPLAY

Figure 19(a). Bonded Scarf Joint Input

```
                    BONDED -- SCARF JOINT
                  ANALYSIS NAME - BOND-12A

                      2 BOND SURFACES
BASIC DATA:
        LOAD TYPE     - 1 (TENSION)
        LOAD (LB/IN) - 10000.
        OVERLAP (IN) -  2.000

ADHESIVE PROPERTIES:
        MAX. SHEAR STRAIN            1.10     ELASTIC SHEAR STRENGTH (PSI)    4000.
        BOND THICKNESS     (IN.)     .005     LINEAR ELASTIC MODULUS (PSI)   70000.
        OPERATING TEMP.    (F.)       70.     EL.-PL. SHEAR STRENGTH (PSI)    5000.
        CURE TEMPERATURE   (F.)      120.     NON-LINEAR EL. MODULUS (PSI)   50000.

ADHEREND PROPERTIES:                 (LEFT)       (RIGHT)
        THICKNESS                    .10          .20
        YOUNG'S MODULUS    (PSI)     .150E+08     .100E+08
        POISSON'S RATIO              .40          .30
        THERMAL COEFF.               .0000000     .0000130
        YIELD STRENGTH     (PSI)     1500 [illegible].    70000.

INTERNAL STRESSES (PSI):
      REMOTE ADHEREND STRESS - LEFT  - 100000.
                             - RIGHT -  50000.
      PEAK ADHESIVE SHEAR:  OVERLAP     STRESS     STRAIN   END
                              2.00       3429.      .0490    L

*  OUTPUT TO PRINT FILE *  OUTPUT TO SAVE FILE   *  RE-ANALYZE  *  RETURN  *
```

Figure 19(b). Bonded Scarf Joint Output (Load≠0, Overlap≠0)

```
                    BONDED -- SCARF JOINT
                    ANALYSIS NAME = BOND-19C

                    2 BOND SURFACES

BASIC DATA:
        LOAD TYPE     =  1 (TENSION)
        LOAD (LB/IN)  =     0.
        OVERLAP (IN)  =  0.000

ADHESIVE PROPERTIES:
        MAX. SHEAR STRAIN            1.10     ELASTIC SHEAR STRENGTH (PSI)     4000.
        BOND THICKNESS     (IN.)     .005     LINEAR ELASTIC MODULUS (PSI)    70000.
        OPERATING TEMP.    (F.)       70.     EL.-PL. SHEAR STRENGTH (PSI)     5000.
        CURE TEMPERATURE   (F.)      120.     NON-LINEAR EL. MODULUS (PSI)    50000.

ADHEREND PROPERTIES:                (LEFT)       (RIGHT)
        THICKNESS                    .10          .20
        YOUNG'S MODULUS    (PSI)     .150E+08     .100E+08
        POISSON'S RATIO              .40          .30
        THERMAL COEFF.               .0000000     .0000130
        YIELD STRENGTH     (PSI)     150000.      70000.

 JOINT STRENGTHS (LB./IN.):
       REMOTE ADHEREND STRENGTH - LEFT  =  15000.
                                - RIGHT =  14000.

       ADHESIVE SHEAR STRENGTHS:  OVERLAP  * ELASTIC  (END)  * TRANSITIONAL  (END)  * EL.-PL.  (END) *
                                   1.00      5852.     L          6090.       L      10000.
                                   2.00     11803.     L         12089.       L      19849.     L
                                   4.00     23754.     L         24059.       L      34796.     L
                                   6.00     35736.     L         36045.       L      49913.     L
                                   8.00     47727.     L         48038.       L      64975.     L
                                  10.00     59721.     L         60034.       L      80012.     L
                                  15.00     89713.     L         90028.       L     117559.     L

*  OUTPUT TO PRINT FILE *   OUTPUT TO SAVE FILE    *  RE-ANALYZE  *  RETURN  *
```

Figure 19(c). Bonded Scarf Joint Output (Load=0, Overlap=0)

```
*** ENDS OF JOINT HAVE BEEN INTERCHANGED ***

                         BONDED -- SCARF JOINT
                        ANALYSIS NAME = BOND-19D

                            2 BOND SURFACES

BASIC DATA:
      LOAD TYPE     =  1 (TENSION)
      LOAD (LB/IN) =     0.
      OVERLAP (IN) =  2.000

ADHESIVE PROPERTIES:
      MAX. SHEAR STRAIN           1.10     ELASTIC SHEAR STRENGTH (PSI)     4000.
      BOND THICKNESS     (IN.)    .005     LINEAR ELASTIC MODULUS (PSI)    70000.
      OPERATING TEMP.    (F.)      70.     EL.-PL. SHEAR STRENGTH (PSI)     5000.
      CURE TEMPERATURE   (F.)     120.     NON-LINEAR EL. MODULUS (PSI)    50000.

ADHEREND PROPERTIES:             (LEFT)        (RIGHT)
      THICKNESS                  .10           .20
      YOUNG'S MODULUS    (PSI)   .150E+08      .100E+08
      POISSON'S RATIO            .40           .30
      THERMAL COEFF.             .0000000      .0000130
      YIELD STRENGTH     (PSI)   150000.        70000.

 JOINT STRENGTHS (LB./IN.):
     REMOTE ADHEREND STRENGTH - LEFT  =  15000.
                              - RIGHT =  14000.
     ADHESIVE SHEAR STRENGTHS: OVERLAP  * ELASTIC  (END) * TRANSITIONAL  (END) * EL.-PL.  (END) *
                                 2.00     11803.    L         12089.       L      19849.     L

* OUTPUT TO PRINT FILE *  OUTPUT TO SAVE FILE  * RE-ANALYZE * RETURN *
```

Figure 19(d). Bonded Scarf Joint Output (Load=0, Overlap≠0)

SECTION VI

SELECTIVE OUTPUT PROCESSING

Main JOINT option 2 provides the user with the capability of outputting solutions that are contained on the SAVE file. The user is given the option of either viewing the output on the terminal display screen, or writing the solutions to the PRINT file for later disposition.

Except for the bonded stepped-lap solutions, each will fit on one page and will look identical to the displayed output following the analytical problem execution step. A bonded stepped-lap solution will contain the complete output on several pages if necessary.

Figure 20 contains a page containing a typical example for selecting solutions to be written to the PRINT file.

SELECTING SOLUTION NAMES

The names of all the solutions contained on the SAVE file will be displayed.

The user picks each solution name to be processed by placing the terminal crosshair or tablet cursor on the name and transmitting the screen location. The program will identify those names to be processed by underlining them on the screen.

CORRECTIONS

If the user wishes to have the underline removed from a name, simply pick the name a second time. The entire screen will be re-displayed without an underline for that name.

RETURN

Any time before execution, the user may exit this mode by selecting the RETURN box. This will immediately clear the screen and return the user to the main menu.

EXECUTE

Print File

Selecting EXECUTE will display

SOLUTIONS BEING WRITTEN TO PRINT FILE

at the lower left portion of the screen. After each underlined solution has been read from the SAVE file and written to the formatted PRINT file, a COMPLETE message will be displayed. When execution is complete, the user will automatically be returned to the main menu. See figures 20 (a) and (b).

Screen Display

After EXECUTE is selected, the screen will be cleared and the complete input and output data for the first selected solution will be displayed, followed by an END OF DATA message. The display will remain on the screen until the user transmits <u>any</u> screen location. The process of clearing the screen, displaying the next solution, and waiting continues for each of the selected names. When the last solution has been displayed, continuing will automatically exit this mode and return the user to the main menu.

Figure 21 shows the page displayed for electing to use the screen to display the solution picked.

```
                    COMPOSITE JOINT DESIGN PROGRAM

          ---->     CODE    OPTION
                      1 =   ANALYZE JOINT
                      2 =   SELECTIVE OUTPUT OF SOLUTIONS FROM SAVE FILE
                      3 =   CONSOLIDATE SOLUTIONS ON SAVE FILE
                      4 =   EXIT
ENTER CODE: 2
IS OUTPUT TO BE DISPLAYED? (1=YES; OTHERWISE WILL COPY TO PRINT FILE): 0
```

Figure 20(a). Selective Output Processing Option

SELECTIVE OUTPUT OF SOLUTIONS TO PRINT FILE

BOLT1-1 BOLT4-1 BOND5-1 BOND7-1 BOND8-1 BOND9-1 BOND9-2 BOND9-3 BOND9-4 BOND9-6

BOND9-7 BOND9-8 BOND9-9 BOND9-10 BOND9-9 BOND9-7

RETURN

EXECUTE

PIC NAMES FOR COPY TO PRINT FILE

SOLUTIONS BEING WRITTEN TO PRINT FILE
(COMPLETE)

Figure 20(b). Selective Output of Solutions To Print File

SELECTIVE DISPLAY OF SAVE FILE SOLUTIONS

BOLT1-1 BOLT4-1 BONDS-1 BONB7-1 BONDS-1 BOND9-1 BOND9-2 BOND9-3 BOND9-4 BOND9-6

BOND9-7 BOND9-8 BOND9-9 BOND9-10 BOND9-9 BOND9-7

RETURN

EXECUTE

PIC SOLUTIONS TO BE DISPLAYED

Figure 21(a). Selection of Save File Solutions For Display

```
BALANCED BOLTED DOUBLE-LAP COMPOSITE JOINT ANALYSIS PRINTOUT
                 ANALYSIS NAME - BOLT1-1

CODE      INPUT DATA:                          VALUE

NX           JOINT LOAD  (LB./IN.)             2000.
FS           JOINT M.S. TENSION FACTOR          1.00
TEMP         JOINT TEMP  (DEG. F.)               0.
MATL         % 0-DEGREE GRAPHITE PLIES            0
BOLT         BOLT TYPE                         1 (TITANIUM)
N            NO. OF BOLT ROWS                     1

T            JOINT THICKNESS   (IN.)           .079
D            BOLT DIAMETER     (IN.)           .188
W            BOLT SPACING      (IN.)           .811
             W/D RATIO                        4.323
             6-D ROW SPACING                  1.125


          OUTPUT DATA:

             JOINT WEIGHT    (LB/IN)         .0899

                SUMMARY OF BOLT ROW STRENGTHS

          BOLT   % OF LOAD     MARGIN OF    FAILURE
          ROW    TRANSFERRED    SAFETY       MODE

           1        100           -.00       TENSION

*** END OF DATA ***
```

Figure 21(b). Example Solution Display

SECTION VII

CONSOLIDATION OF THE SAVE FILE

Main menu option #3 allows the user to remove obsolete solutions from the SAVE file. The file need not contain the 100 solution limit. This option may be used any time the user elects to remove selected solutions from the active SAVE file.

All solutions contained on the SAVE file are displayed as shown in Figure 22.

SELECTING NAMES

The user picks a name to be purged from the SAVE file by positioning the crosshair or tablet cursor or the name and transmitting the screen location. Valid locations are accepted and identified by underlining the name. Repeat this procedure for each name to be purged.

CORRECTIONS

Any time the user wishes to have the underline removed from a name, simply pick the name again. The entire screen will be re-displayed without an underline for that name.

RETURN

Any time before execution the user may exit this mode by selecting the RETURN box. This will immediately clear the screen and return the user to the main menu.

EXECUTE

When all the names to be purged have been underlined, selecting the EXECUTE box will copy all solutions but those underlined back onto the SAVE file. When finished, a COMPLETE message will be displayed on the screen, the screen will then be cleared and the user returned to the main menu.

CONSOLIDATION OF SAVE FILE SOLUTIONS

BOLT1-1 BOLT4-1 BOND5-1 BOND7-1 BOND8-1 BOND9-1 BOND9-2 BOND9-3 BOND9-4 BOND9-6

BOND9-7 BOND9-8 BOND9-9 BOND9-10 BOND9-9 BOND9-7

RETURN

EXECUTE

PIC NAMES TO BE PURGED FROM SAVE FILE

Figure 22. Consolidate Solutions On Save File

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